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AUTHOR Woods, Robert H.; And Others
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ABSTRACT

A 368-frame programed instruction course in the operation of the Tektronix 545A Oscilloscope, together with a response booklet and an administrator's manual, is contained in the report. The oscilloscope operations taught in the program are: preset and calibration, voltage measurement, frequency measurement, comparison of waveshape to waveshape, and standard and high accuracy time-base measurements and comparisons. These operations reflect a behavioral analysis of maintenance usage of this test equipment in conjunction with electronic communications equipment. The appendix contains technical information for building a small signal generator for use with the program. (Author/KB)

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AN INSTRUCTIONAL PROGRAM ON OPERATION OF THE TEKTRONIX 545A OSCILLOSCOPE

ROBERT H. WOODS
FRANK J. TRUDO
WILLIAM J. PIEPER

APPLIED SCIENCE ASSOCIATES, INC.

JUNE, 1966

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
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IR004194

FOREWORD

This report represents a portion of the exploratory development program of the Technical Training Branch, Training Research Division, Behavioral Sciences Laboratory. The research was documented under Project 1710, "Human Factors in the Design of Training Systems," Task No. 171007, "Automated Training and Programmed Instruction."

Dr. Gordon A. Eckstrand was the project scientist. Dr. Ross L. Morgan was task scientist. Mr. John P. Foley, Jr. was contract monitor. The research was conducted under Contract No. AF 33(615)-1414 with Applied Science Associates, Inc., Valencia, Pennsylvania. Dr. John D. Folley, Jr. was the principal investigator. Mr. Robert H. Woods and Mr. Frank J. Trudo were the on-site representatives of Applied Science Associates, Inc. The study was conducted in cooperation with the 6940 Security Wing (USAFSS), Goodfellow Air Force Base, Texas. Colonel John P. Shean, then Deputy Commander for Training, and his successor, Colonel John T. Stevenson, created an environment within which the basic study on which this program is based could be conducted. This research began in February 1964 and was completed in December 1965.

The original program was prepared by Robert H. Woods and Frank J. Trudo. The revision of the program as presented in this report was prepared by William J. Pieper of Applied Science Associates, Inc., as was the detailed documentation on the signal generator (TSG-1) in Appendix I. Credit is, also, due to S/Sgt Phillip Kennison who had developed an Audio Visual Program for the 545A Oscilloscope prior to the work of the authors.

This technical report has been reviewed and is approved.

WALTER F. GRETHER, PhD
Technical Director
Behavioral Sciences Laboratory
Aerospace Medical Research
Laboratories

ABSTRACT

This report contains a 368 frame, book program, for teaching the operation of the Tektronix 545A Oscilloscope together with a response booklet and administrator's manual. The oscilloscope operations included in the program are preset and calibration, voltage measurement, frequency measurement, comparison of waveshape to waveshape standard and high accuracy time-base measurements and comparisons. These operations reflect a behavioral analysis of maintenance usage of this test equipment in conjunction with electronic communications equipment. The appendix contains technical information for building a small signal generator for use with this program.

TABLE OF CONTENTS

SECTION — Page No.

I. Introduction — 1

II. A Book Program for Teaching the Use of the 545A Tektronix Oscilloscope — 5

  A. Introduction to the Oscilloscope — 11

  B. The Measurement of Frequency — 41

  C. The Measurement of Voltage — 81

  D. Dual Trace Operation — 123

  E. Magnification and High-Accuracy Time-Base Measurements — 163

  F. A Little More about the Model 545A — 205

III. 545A Response Booklet — 217

Appendix I
Technical Information on the TSG-1 Signal Generator for Use with the Instructional Program on Operation of the Tektronix 545A Oscilloscope — 233

Appendix II
Administrator's Manual for Tektronix 545A Instructional Program — 245

SECTION I

INTRODUCTION

The instructional program that comprises the major portion of this report is a revision of a program that was originally developed for use in an experimental comparison of modes of presentation of instructional material. That experiment is described in another technical report.*

After the experimental study, the program was revised in the light of the results of the study and the experience gained with the program. The revised version has not been tested.

The original program was based upon an analysis of the tasks involved in performing five blocks of operations on the oscilloscope. These blocks of operations, with the tasks in each, are:

1. Preset and calibration

    1.1 Preset controls
    1.2 Position and focus display
    1.3 Evaluate display

2. Voltage measurement

    2.1 Define measurement problem
    2.2 Obtain display
    2.3 Evaluate display

3. Frequency measurement

    3.1 Combine 1.1, 1.2, 1.3, and 2.1
    3.2 Obtain display
    3.3 Evaluate display

4. Comparison of Waveshape to Waveshape Standard

    4.1 Combine 2.1 and 3.2
    4.2 Evaluate waveform

---

* Folley, J.D., Jr., Woods, R.H. and Foley, J.P., Jr., Comparison of Three Modes of Instruction for the Operation of a Complex Oscilloscope. Being prepared for publication as an AMRL Technical Report.

5. High Accuracy Time-base Measurements and Comparisons

   5.1 Display selected portions of waveform using both time bases.
   5.2 Amplitude comparison of two waveforms using dual trace display.
   5.3 Time base comparison of two waveforms using dual trace display.
   5.4 Frequency comparison of dual trace waves.

Use of the program requires a Tektronix Type 545A oscilloscope (Figure 1) and the following accessories:

1 TSG-1 signal generator (see next paragraph)

2 type P 6000 probes (Tektronix)

1 red ground lead

The TSG-1 signal generator was designed specifically for this program. It provides all of the signals needed for use of the program. The signals it provides are thought to be an adequate sample of practice signals. Technical details of the TSG-1 are given in Appendix I.

Experimental subjects took from about four to seven hours to complete the program, which was run in two sessions. The criterion test associated with the program is fully described in (reference: 545A Experimental Report).

An Administrator's Manual for the program comprises Appendix II.

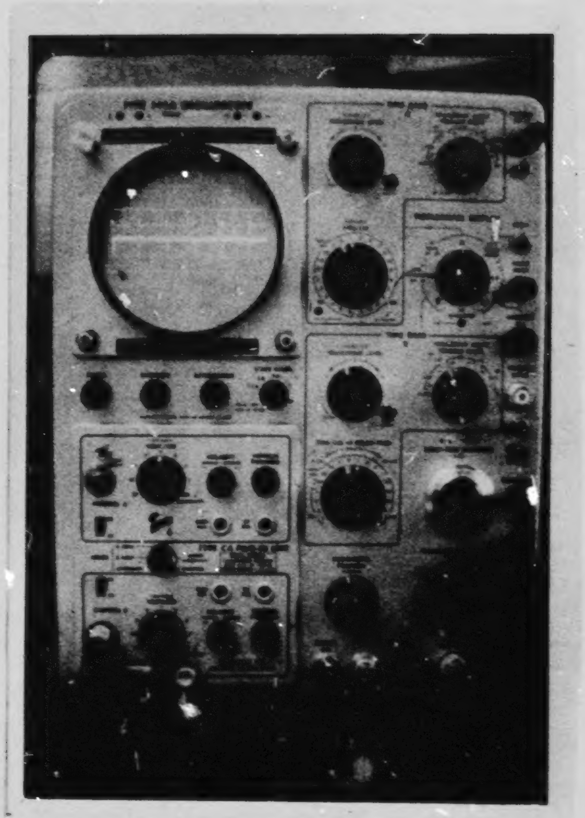


Figure 1. The 545A Oscilloscope

READ THIS ENTIRE PAGE BEFORE PROCEEDING

Introduction and Instruction for Use

General

This book contains an instructional program which will guide you in learning to use the Model 545A Oscilloscope to measure voltage and frequency, and to assess other characteristics of waveshapes.

The program assumes that you are familiar with the more conventional types of oscilloscopes and can solve simple problems involving multiplication and division of decimal numbers.

Materials Required

1) This book.
2) One Response Booklet, in which you write.
3) One 545A Oscilloscope, with Type CA Plug-In Unit, two P-6006 or P-6000 probes, and one ground lead.
4) One TSG-1 Signal Generator.
5) One Cover Card.

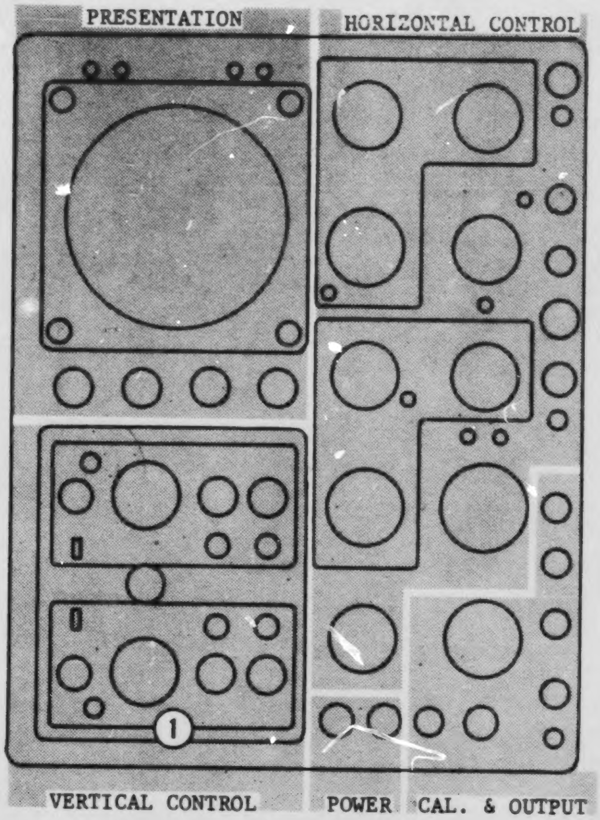
Procedure for Using the Program

You start by reading the first paragraph, or "frame", and doing what it tells you. Then go on to the next frame, etc. In some frames you will be directed to certain figures. These are located on the left, facing page. If you are referred to the "figure on the left (2)", this means you should look at the item labelled "2" in the figure on the back of the previous page. You may just see "(2)" at the end of a sentence. This means that you should refer to indicator number 2 on the figure to which you have already turned. Usually this indicator will help you find something referred to in the sentence. It is put at the end so that you will read the whole sentence and get its meaning before you do something.

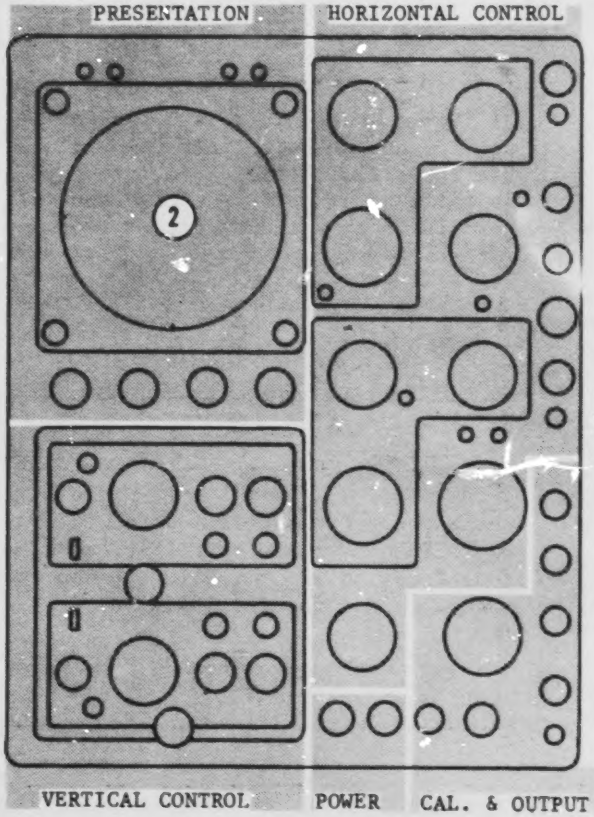
You will be instructed to make calculations or to fill in blanks in certain frames. All such responses are made in the Response Booklet. DO NOT WRITE IN THE PROGRAM BOOK. After you have written your response, you can check it against the correct response given at the left of the frame immediately following.

As you can see, it would be easy to look at the correct response before you decide what the response should be. But if you want to learn, you will follow the correct procedure as given above.

Now turn to Frame 1.1 and begin the program.


PRESENTATION
HORIZONTAL CONTROL
①
VERTICAL CONTROL
POWER
CAL. & OUTPUT

	1.1 The figure at the left is a drawing of the Model 545A Oscilloscope. Notice that the picture shows the front of the oscilloscope divided into five sections. You are going on a short clockwise tour of the 545A with the help of this figure.
	1.2 Locate the POWER section on the figure and then locate the POWER section on your instrument. It has an indicator lamp and a _____. (Write your answer in the space provided for Frame 1.2 on the Response Sheet.)
switch	1.3 Using the figure to assist you, locate the VERTICAL CONTROL section on your instrument. This is called the Type CA Plug-In Unit. Unscrew the knurled knob and pull the unit partially out, using this knob as a pull (1). The unit which slides out is the Type CA _____ - _____ Unit. Reseat the Unit and tighten the knob.
Plug-In	1.4 The Type CA Plug-In Unit corresponds to the vertical input of other oscilloscopes. Input to, and adjustments on, the CA Plug-In Unit determine the height of a waveform, the vertical position of the trace, or both. When a signal is being displayed, the CA Plug-In Unit will determine the ______ position of the trace, the _____ of a waveform, or both.


PRESENTATION
HORIZONTAL CONTROL
2
VERTICAL CONTROL
POWER
CAL. & OUTPUT

vertical

height

1.5

With the help of the figure at the left, locate the PRESENTATION section on your oscilloscope. One of the elements in this section is the Cathode Ray Tube or CRT (2). Notice the grid on the face of the CRT of your instrument. There are _____ (how many) horizontal grid lines.

5

1.6 Locate the HORIZONTAL CONTROL section. This section is concerned with time-base and frequency measurements of a signal. Look at your instrument and read the labels of the controls in this section. Adjustments here determine the width or the horizontal position (or both) of the display. The HORIZONTAL CONTROL section has two time bases, TIME BASE _____ and TIME BASE _____.

A

B

1.7

Your tour of the 545A ends with the CALIBRATION AND OUTPUT section. Locate this section and notice the 6 different types of outputs. On your Response Sheet list the four outputs along the right hand edge of the instrument.

DEL'D TRIG.

+ GATE B

+ GATE A

SAWTOOTH A

1.8

Notice that there are two more outputs along the bottom edge. One of these is the _____ _______ _________ and the other is the ______ ________.

VERT. SIG. OUT CAL. OUT	**1.9** Looking at your oscilloscope, you will notice that many of the black knobs have red knobs mounted top-center. Turn one of the black knobs and then the red knob mounted on top of it. Turning the red knob (does/does not) ______ turn the black knob at the same time.
does not	**1.10** Look at the HORIZONTAL DISPLAY control. Notice that the words "HORIZONTAL DISPLAY" are printed in black. The words "HORIZONTAL DISPLAY" refer to the _____ colored knob and the words "5X MAGNIFIER" refer to the ______ colored knob.
black red	**1.11** The function of the red control is always printed in red above or below the control cluster. The function of the black control switch may be printed in black, blue, or green. Find a switch function label with each of these colors on your instrument.
	1.12 You are to learn to make a number of different types of measurements using the Model 545A. Most of these measurements are best made in a certain sequence. There are five general steps in making a measurement. Try to learn these steps as you continue reading. They will be underlined and capitalized

1.13 Step 1.

As with just about any measuring instrument, the first step is to DEFINE YOUR PROBLEM. You must first determine that measuring at a particular test point with an oscilloscope will give you the information that you need. You may then refer to schematics and technical papers to get some idea of the voltage and frequency ranges to be expected. You will better understand where to set your controls before measurement if you D________ Y________ P________.

DEFINE YOUR
PROBLEM

1.14 Step 2.

ASSEMBLE EQUIPMENT. Better test instruments generally have a number of accessories. These are useful for many different problems. This is true of the 545A. Check now to see that you have at your position:

a. Two 10X probes (P6000 or P6006)
b. Banana adaptors for the probes
c. One ground lead with banana plugs
d. Type CA Plug-In Unit (Plugged in the instrument)

1.15

After you define your __________, you should A__________ E__________.

---

problem

ASSEMBLE EQUIPMENT

1.16 Step 3.

When you have defined your problem and assembled the necessary equipment the third step is to TURN ON AND CHECKOUT your instrument. You will do this shortly. Whenever you turn the POWER switch of the 545A to the ON position, there is a short delay before voltage is applied to all parts of the instrument. This time may be used to preset some of the controls for checking out the instrument.

1.17

The steps you have learned so far are:

1. __________ __________ __________
2. ASSEMBLE __________
3. T__________ O__________ AND C__________

1.18 Step 4.

1. DEFINE YOUR PROBLEM
2. EQUIPMENT
3. TURN ON AND CHECKOUT

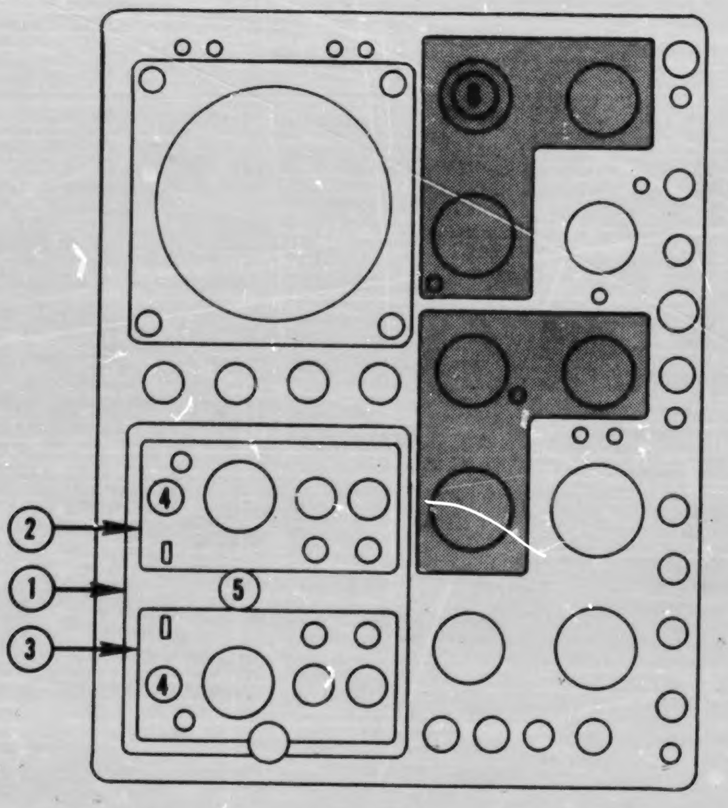
The 545A is equipped with a calibration section. The output of this section permits you to check the accuracy of your instrument and its probes before making any voltage or waveshape measurements. The fourth step is to PRESET AND CALIBRATE your instrument.

1.19 Step 5.

The fifth and final step in this general measurement procedure is to DISPLAY AND EVALUATE A SIGNAL by connecting a ground line from the equipment under test to the oscilloscope ground and connecting the probe to the equipment test point.

1.20

Write the five steps of this procedure on your Response Sheet and confirm your answer.



1. DEFINE YOUR PROBLEM
2. ASSEMBLE EQUIPMENT
3. TURN ON AND CHECKOUT
4. PRESET AND CALIBRATE
5. DISPLAY AND EVALUATE SIGNAL

1.21

Now look at the figure on the left. Find the Type CA Plug-In Unit on your instrument, again using the figure as a guide (1). Notice that the Unit contains CHANNEL A and CHANNEL B (2) (3). Closely compare the two sections of the panel. Notice that each has its own input jack (4). There are how many controls on CHANNEL A which are not found on CHANNEL B? __________.

none (0, zero)

1.22

If you wish to use CHANNEL A or CHANNEL B, or both at once, you will make your selection using the MODE switch (5). Locate the MODE switch on your instrument. You could select CHANNEL A by placing the __________ switch in the __________ __________ position.

MODE

A ONLY

1.23

Put the MODE switch in the A ONLY position. Put a check on your Response Sheet next to the controls which are located on the PRESENTATION section of your oscilloscope.

a

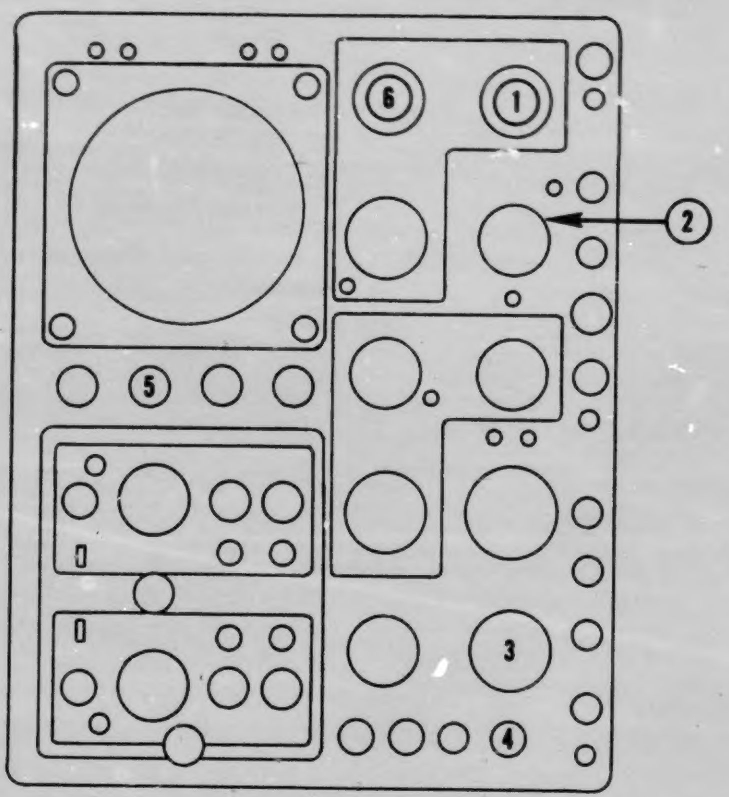
c

d

g

1.24

Look at the HORIZONTAL CONTROL section of your scope. There are two "Time Bases" on the 545A. There is a colored line surrounding each Time Base. Each Time Base has __________ (how many) controls. The two Time Bases are TIME BASE __________ and TIME BASE __________.

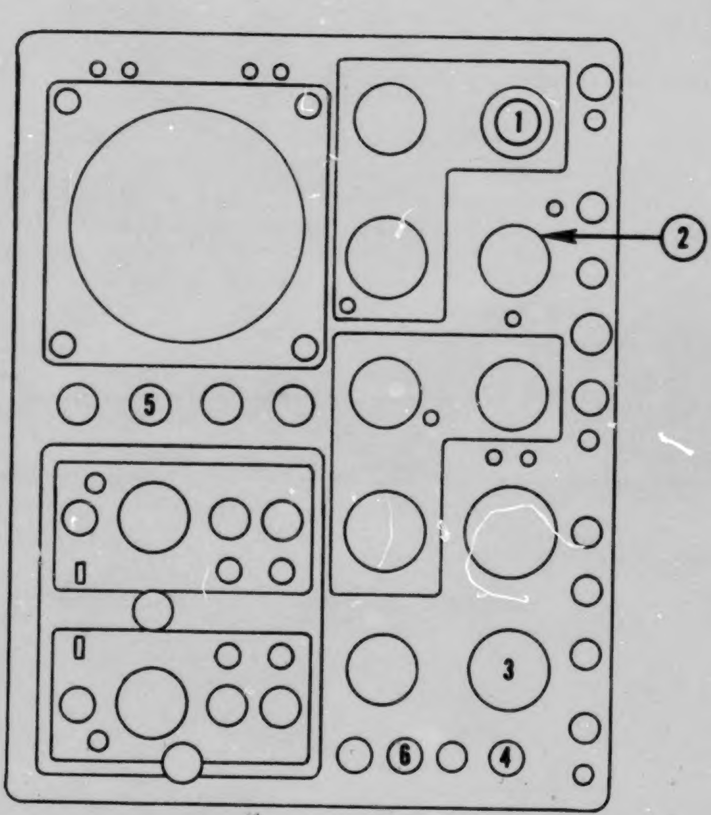


three (3) A B	1.25 Look at your oscilloscope and find TIME BASE A. Now find the STABILITY control in TIME BASE A (6). It is a __________ (color) knob, turn it clockwise until it stops. Notice that the TRIGGERING LEVEL control or ______ (color) knob did not move.

red black	1.26 Now find the TRIGGERING MODE control in TIME BASE A (1). Turn this control or _________ (color) knob counter-clockwise to the AUTO position.

red	1.27 The control used to select the time base and type of display is called HORIZONTAL DISPLAY (2). Look at your oscilloscope and find this control.

	1.28 Notice the large A and B positions of this control, they refer to Time Bases A and B. To select TIME BASE A you would set the HORIZONTAL DISPLAY to __________. Do so now.



A

1.29

Locate the AMPLITUDE CALIBRATOR on your instrument (3). The output of the AMPLITUDE CALIBRATOR is taken from the CAL. OUT jack (4). The voltage of the CAL. OUT jack is controlled by the setting of the AMPLITUDE CALIBRATOR. The settings of the AMPLITUDE CALIBRATOR range from ________ to ________ volts.

.2 millivolts

100

1.30

You do four things when you turn on the oscilloscope properly. They should be done in the correct sequence. The first step is to turn the POWER switch to the off position. The "down" position of the POWER switch is the __________ position. Turn the switch off now.

---

off

1.31

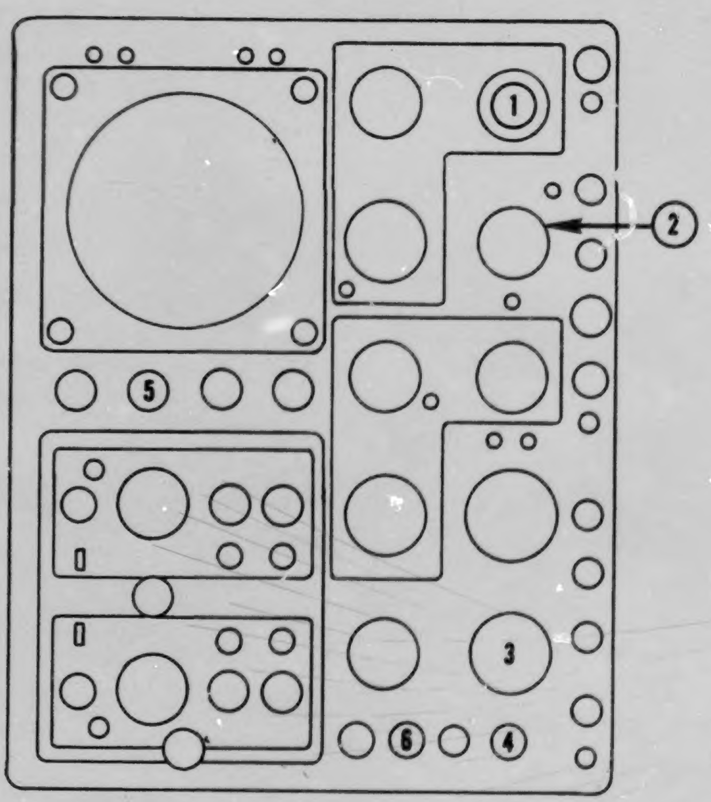
Locate the INTENSITY control on your scope (5). Turn it fully counter-clockwise. You have completed step two in the turn-on procedure.

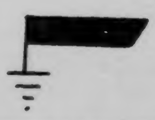
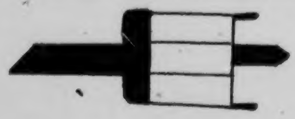
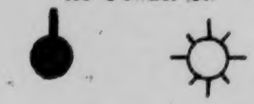
1.32

Examine the ac power plug. Notice the three prongs. The longer prong provides a ground connection for the oscilloscope. Proper use of the Model 545A requires such a plug. The third step in the turn-on procedure is to place the plug into the wall outlet. Do this now.

The steps you have learned so far are:

1. POWER switch __________.
2. INTENSITY control fully __________ __________.
3. Power cord plugged __________.



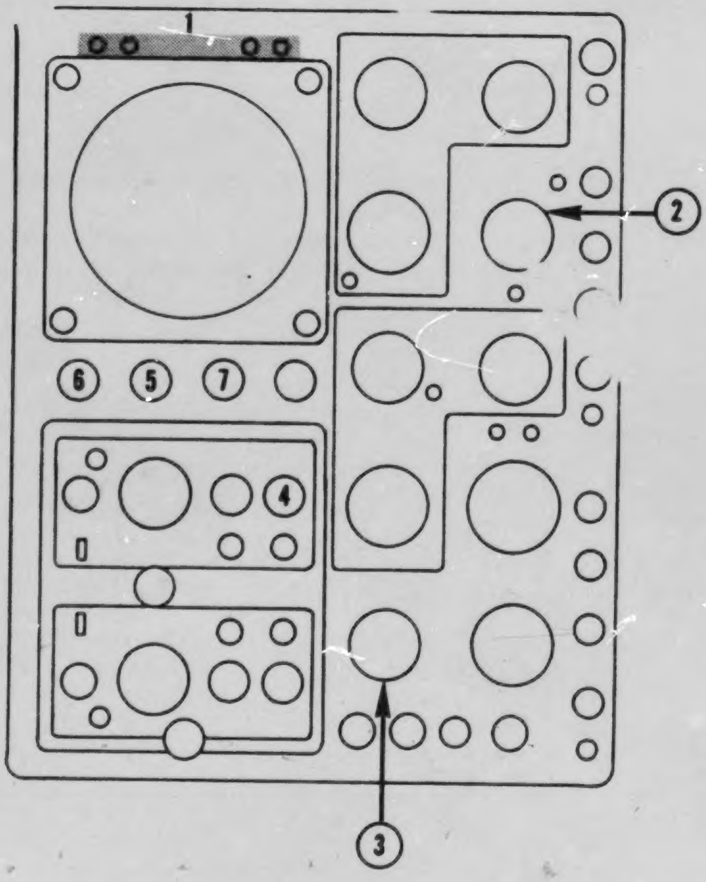
1	AC POWER OFF	
2	INTENSITY CCW	
3	PLUG IN GROUNDED POWER LINE	 
4	AC POWER ON	

1. off 2. counter-clockwise 3. in (into outlet)	1.33 The last step in the turn-on procedure is to turn the POWER switch to the ON position. Do so now. Notice that the red indicator lamp glows when the POWER switch is on (6). Your turn-on procedure is now complete.

	1.34 Look again at the order of events in the figure on the left. There is a reason for the procedure to be in this order. The POWER switch should be off before the wall connection is made, to prevent arcing at the plug and to prevent surges of current within the oscilloscope while the wall plug is being inserted. The INTENSITY control should be turned down to prevent burning of the tube. While the set warms up, you always have time to preset some other controls. List in order on your Response Sheet the four steps of the turn-on procedure.

1. PWR. sw. off 2. INTENSITY counter clockwise 3. Plug into outlet 4. PWR. sw. on	1.35 The MODE switch at the CA Plug-In Unit is in the __________ __________ position. The HORIZONTAL DISPLAY switch is in the __________ position. In TIME BASE A the STABILITY control is in the extreme __________ position and the TRIGGERING MODE is in the __________ position.

A ONLY A clockwise AUTO	1.36 Put the controls mentioned above in the positions given at the left if they are not already in these positions.



1.37

Before making any measurements you must check the presentation section of the oscilloscope. The best way to begin is with the sweep off; so move the HORIZONTAL DISPLAY switch clockwise to X10 of EXT.

1.38

Look at the figure on the left and notice the area indicated by (1). Find this area on your instrument. In this area locate four small arrows each beside a small lamp. When any lamp is lit, the arrow nearest that lamp indicates the position of your trace or spot if it is not on the visible portion of the CRT. You will use these arrows and lamps or "position indicators", as they are called, when you position the spot.

1.39

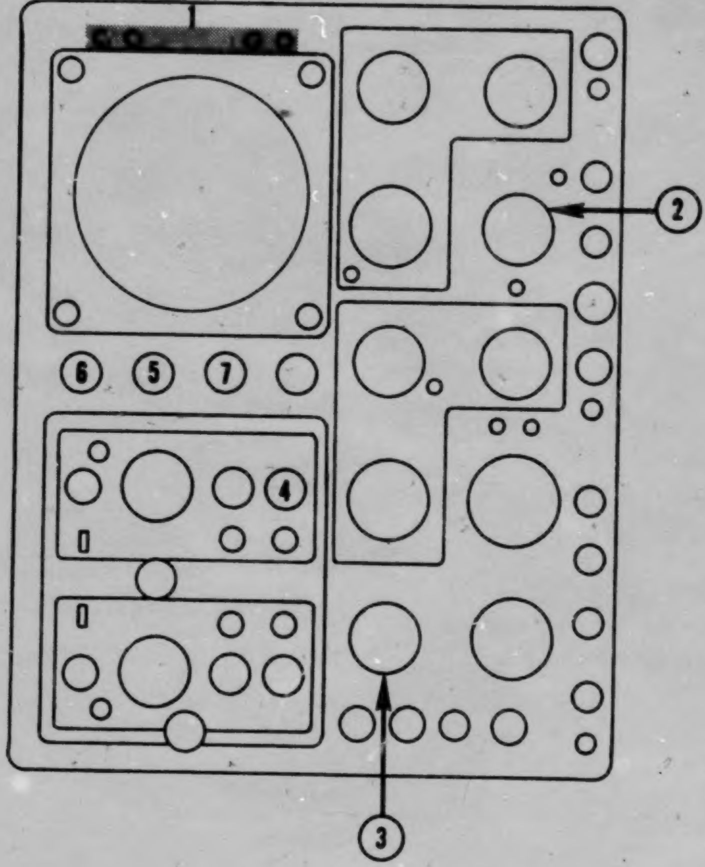
The pair of indicators on the right are the horizontal ___________ indicators and the pair on the left are the ___________ position indicators.

position

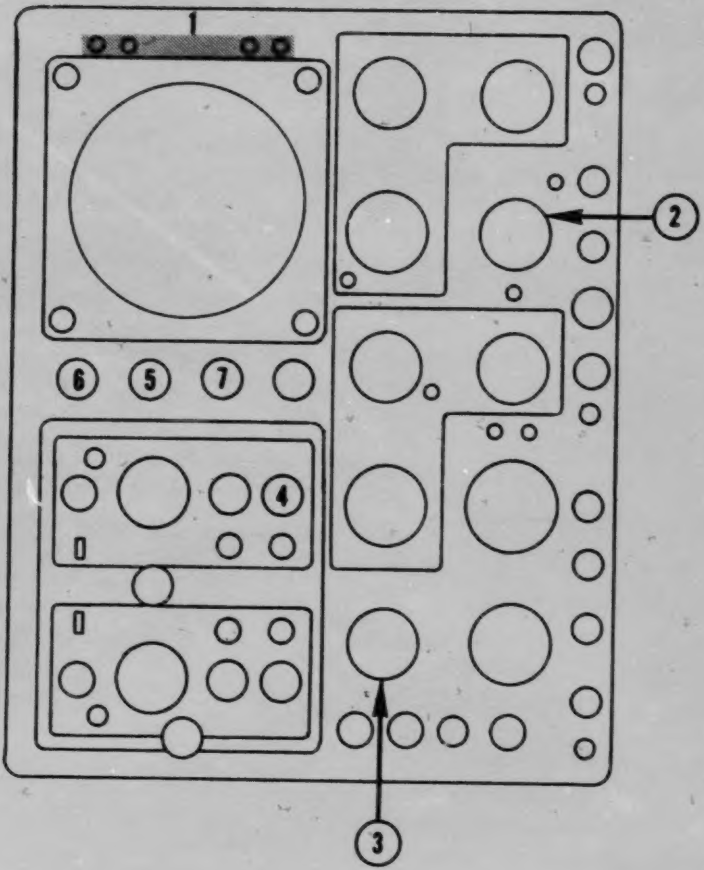
vertical

1.40

Find the HORIZONTAL POSITION control on your scope (3). While you watch the horizontal position indicators, rotate this control back and forth. Now set the control so that both lamps are out.



	1.41 Now find the VERTICAL POSITION control of CHANNEL A (4). Watching the vertical position indicators, rotate this control back and forth. Now set this control so that both lamps are out.
	1.42 Although you can't see it because the intensity is turned down, you have just centered the spot and are ready to proceed. When all four position indicators are extinguished the __________ is approximately __________.
spot centered	**1.43** Read this frame through before you touch any more controls. You will turn the INTENSITY control (5), slowly clockwise until a spot appears. DO NOT turn this control past the 12 o'clock position just because you do not see the spot. If the spot has not appeared by the time the control is at 12 o'clock, carefully adjust the VERTICAL POSITION control on CHANNEL A (4) through its full range or until you see the spot. Turn up the intensity now.
	1.44 If there is a halo around the spot, reduce the intensity until the halo disappears. If you have the spot, go to the next frame. If you have not seen it, return the VERTICAL POSITION control to its former position (both vertical position lamps extinguished) and perform the same type of operation on the HORIZONTAL POSITION control (3). If no spot has appeared, go back and check your operations and settings again.



29

1.45

The FOCUS and ASTIGMATISM controls allow you to obtain a sharp, clearly defined spot (6) (7). If the spot is extremely small, so that you cannot tell whether or not it is round, turn the FOCUS control to enlarge it (6).

1.46

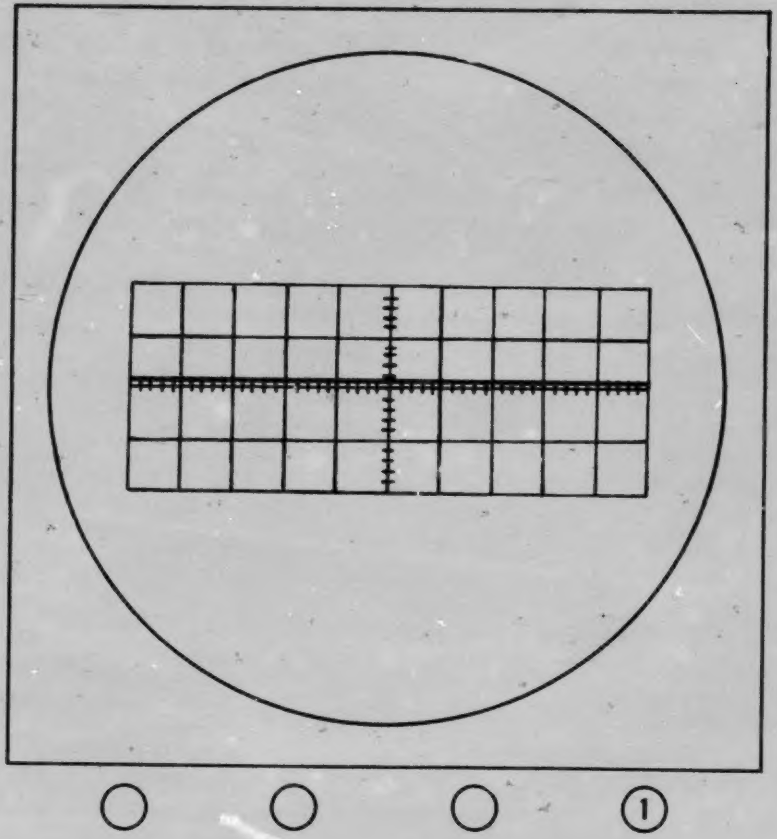
Now turn the ASTIGMATISM control to obtain a perfectly round spot (7). Once the spot is round, turn the FOCUS control to reduce its size as much as possible (6).

1.47

Now move the HORIZONTAL DISPLAY control back to position A (2). You should now see a straight line on the screen. If the line or trace is not visible, slowly increase the intensity.

1.48

Using the HORIZONTAL and VERTICAL POSITION controls, center the trace on the grid of the tube (3) (4). Now notice the horizontal position indicators (1). You see that ________ lamps are on and have approximately __________ brightness.



31

both equal	1.49 Once the ASTIGMATISM control is set to obtain a round spot, all focusing can be done with the _____ control.
FOCUS	1.50 With the trace on your scope face, set the SCALE ILLUM. control to a position where the grid is clearly illuminated for you (1). You may turn this control all the way clock-wise, if you wish, without harm to the scope.
	1.51 Let's review. To checkout the PRESENTATION section of the scope, ______ the spot, using the horizontal and vertical position _______ as guides.
center indicators	1.52 After the spot is centered, increase the ______ until the spot is visible. Then using the _____ control, make sure that the spot is perfectly round.

INTENSITY ASTIGMATISM	1.53 Once the ASTIGMATISM control is set, all focusing can be done with the ________ control.
FOCUS	1.54 You have learned two procedures in this introductory section. The ______ ______ procedure and how to check out the ______ section of the 545A.
turn on presentation	1.55 You have now completed the introduction to the 545A Oscilloscope. If you are not going to continue at the present time, turn the scope off. If you are going on, turn the intensity down until the sweep line goes off. Continue the program.

PART B

THE MEASUREMENT

OF

FREQUENCY

2.1

If you interrupted the program sequence between Section I and II, be sure to turn the scope on and check the presentation section, following the procedures given in Frames 1.30-1.48. Do not go on until you have done this.

2.2

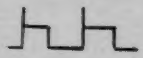
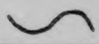
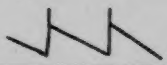
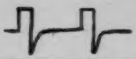
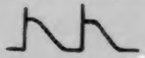
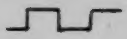
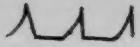
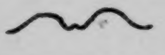
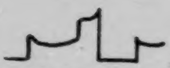
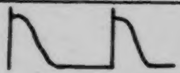
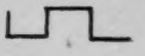
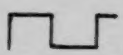
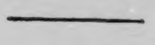
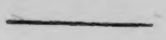
If you can see the sweepline, turn the intensity down while you are working the next few frames, to prevent burning the face of the CRT.

2.3

The reason for checking and adjusting the presentation section of the 545A is that this scope is extremely accurate if used and adjusted properly. If you learn the proper procedures, you will be able to take full advantage of its accuracy.

2.4

By obtaining a sharp, undistorted trace, we avoid errors in measurement that occur when a display is fuzzy or distorted.

FUNCTION SWITCH	JACK	VOLTS	FREQUENCY	PATTERN
1	A	—	—	
2	B	—	—	
3	A	—	—	
4	A	—	—	
4	B	—	—	
5	A	5	250 cps	
5	B	200	—	
6	A	—	—	
8	A	—	—	
8	B	—	—	
9	A	—	—	
9	B	—	—	
10	A	DC	ZERO	
10	B	DC	ZERO	

2.5

This oscilloscope, if used properly, will allow you to make time and frequency measurements with 1% accuracy. Make all your settings carefully and you will find this scope to be an extremely valuable instrument.

2.6

Before we begin the measurement of frequency, do you remember the 5 steps in making a measurement using the 545A? List them on your answer sheet.

1. Define Your Problem.
2. Assemble Equipment.
3. Turn On & Check-Out.
4. Preset & Calibrate.
5. Display & Evaluate Signal.

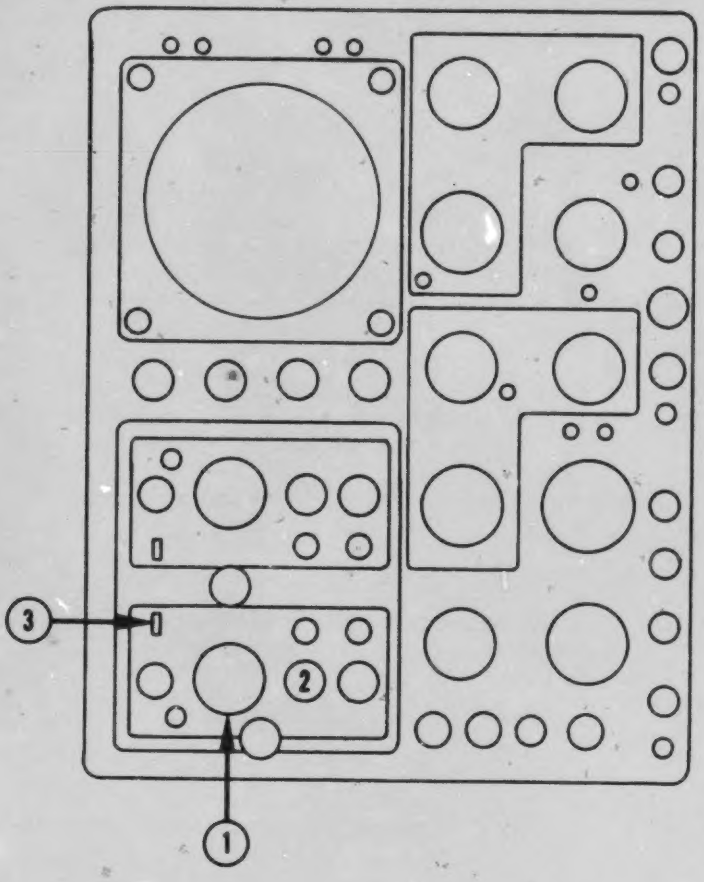
2.7 Your first problem will be to measure the frequency at Jack A of the Signal Generator on your bench, when the Function Switch (FS1) of the generator is at Position 5. Refer to the figure on the left. This diagram shows the Signal Generator outputs. According to this figure, when the Function Switch is at Position 5, the frequency at Jack A should be _____ cycles per second. This defines your problem.

250

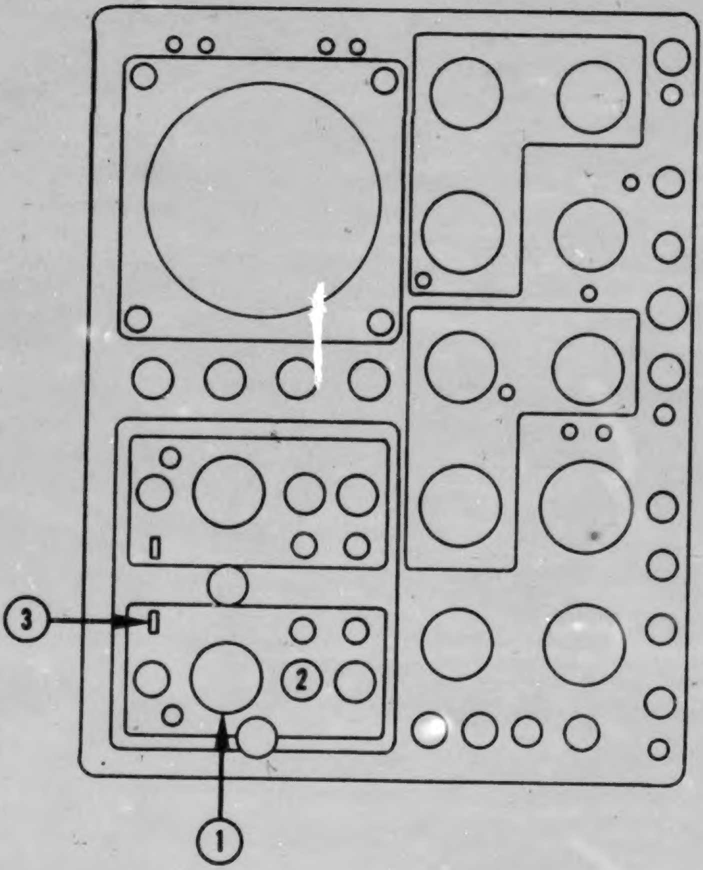
2.8

Now you will assemble your equipment. For this problem, and all other problems in this program, you will use the Type CA Plug-In Unit. You will need one probe, a banana adaptor for the probe, a ground lead, and a power cable to do the job. Check again to see that you have these. You have now assembled your equipment. Attach the banana adaptor to the probe.

	2.9 Since you have just completed the turn on and checkout procedures, we will not repeat them now. However, try to list the steps on your answer sheet in an abbreviated fashion starting with, PWR. sw. off.
1. PWR. sw. off 2. INTENSITY CCW 3. Plug in 4. PWR. sw. on 5. Center spot 6. INTENSITY CW 7. Adjust spot to round 8. Focus 9. Center sweep line	**2.10** We will now PRESET AND CALIBRATE the scope for measuring a frequency of __________ cycles per second, as given in the problem.
250	**2.11** Since CHANNEL A and CHANNEL B at the CA Plug-In Unit are exactly the same, either channel could be selected for use. Please use CHANNEL B for this problem. Locate the MODE switch on the Plug-In Unit and place the switch in position __________ __________.
B ONLY	**2.12** You have just selected CHANNEL B, so the vertical position of the trace is controlled by the __________ __________ VERTICAL POSITION control.



CHANNEL B	2.13 Locate the VOLTS/CM control on CHANNEL B of the Plug-In Unit (1). The position of this control determines the height of the display or the amount of vertical deflection. The deflection is measured in terms of VOLTS/CM (volts per centimeter).
	2.14 When this control is set at 5, an input signal of 5 volts produces 1 centimeter of vertical deflection. With this control set on 5, an input of 10 volts would produce __________ centimeters of vertical deflection.
2 (two)	2.15 The voltage at Jack A of the Signal Generator, when the Function Switch is in Position 5, is 5 volts. If you were using non-attenuating probes and desired the vertical deflection to be 5 CM, you would set the VOLTS/CM at __________.
1	2.16 Since the probes you are using are 10X probes, the signal applied at the probe tip will be reduced by a factor of 10 at the vertical input of the scope. Therefore, if 5 volts is applied to the tip of the probe, the signal at the scope input will be __________ volts or 5/10 volts.

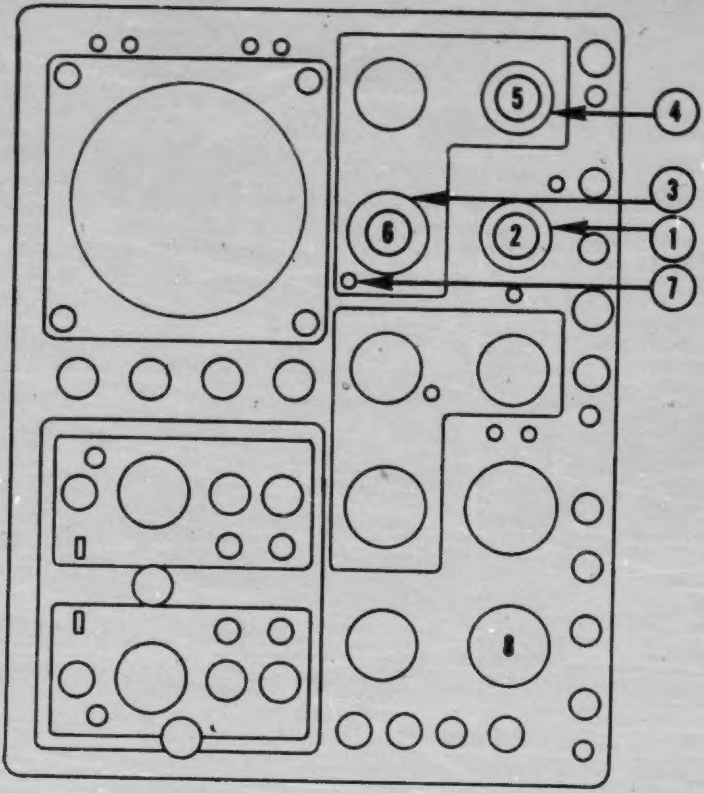


.5 (1/2)	2.17 When using 10X probes, in order to display 5 volts in one centimeter on the scope, you would set the VOLTS/CM control to .5. In this case, however, we want to display 5 volts in 2 CM. Therefore, you would set the control at ________, which is as close to 1/2 of .5 as you can get.

.2	2.18 Set the VOLTS/CM control to .2 now (1). The height of the display is not critical when measuring frequency but you must be able to count the cycles, so the trace must be large enough to see clearly.

	2.19 We will ignore the setting of the VARIABLE red knob until we measure voltages. There are 2 other controls in CHANNEL B which we must be concerned with: the POLARITY control and the AC-DC switch (2) (3).

	2.20 The POLARITY control is used to invert the waveshape and will usually be set in the NORMAL position when measuring frequency. The AC-DC switch will usually be in the DC position. The POLARITY control is usually set at ________ and the AC-DC switch is usually set at ________ when making measurements of frequency.



NORMAL

DC

2.21

There are slight differences between TIME BASE A and TIME BASE B but either can be used for this problem. Please use TIME BASE A. To select TIME BASE A you move the __________ __________ control to position __________ (1).

HORIZONTAL DISPLAY

A

2.22

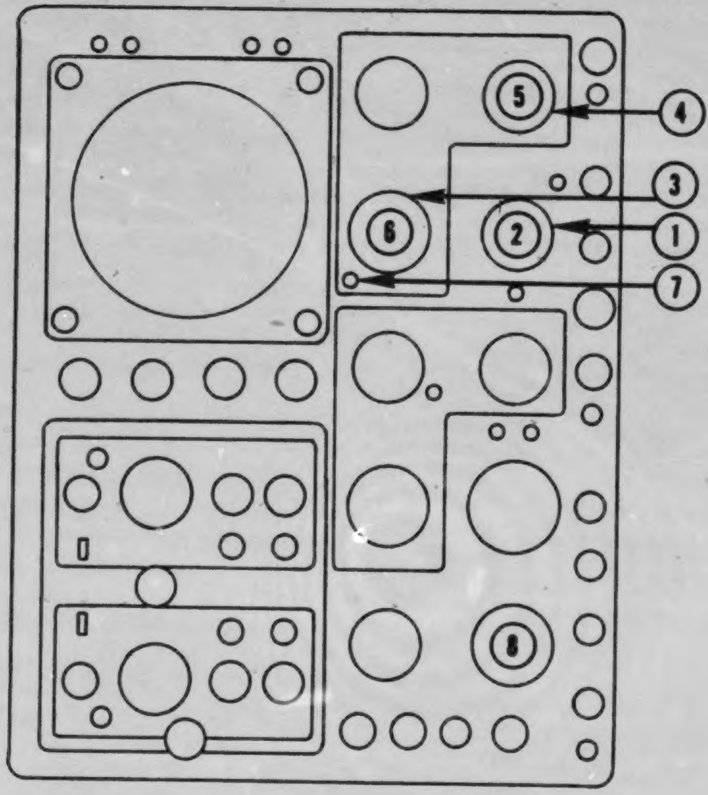
Do it now. If you will look at the settings you have made thus far, you will see that you are using CHANNEL B and TIME BASE A together. Check this. The time bases and channels may be used in any combination. There is no connection between them which requires any particular combination.

2.23

Notice the 5X MAGNIFIER; this control has a very special function and is not used in the measurement of frequency (2). Turn this control to the OFF position. Adjustment of the time base is critical to accurate measurement of frequency; so do the next few frames very carefully.

2.24

Although we already know the frequency to be measured, let's begin by setting the scope for an unknown frequency. When we have finished measuring frequency, you will understand how to set the controls to display a known frequency.



2.25

Find the TIME/CM control in TIME BASE A (3). This controls the time it takes the sweep to move 1 CM across the CRT, just as VOLTS/CM controls the voltage to move the trace 1 CM up the CRT. You have the best chance of seeing some portion of the signal if this control is set near the middle of its range.

2.26

The middle of the range is about .5 milliseconds. So you should set the TIME/CM control at __________ milliseconds. Do this now.

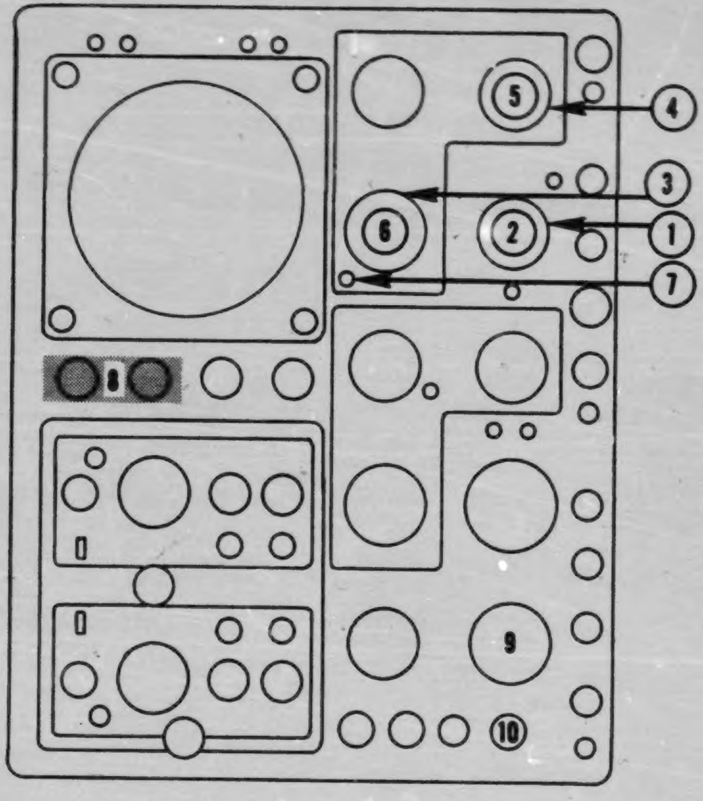
.5

2.27

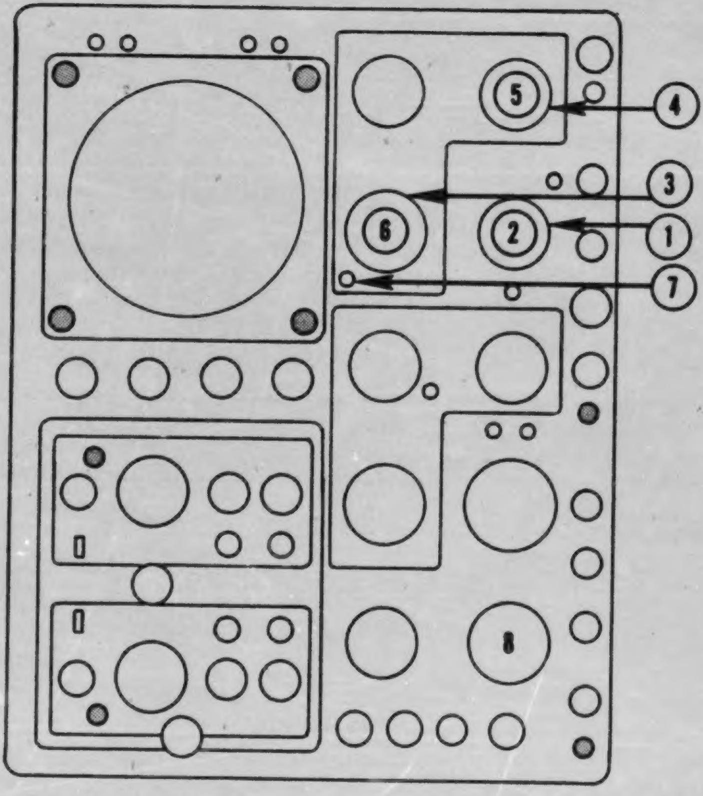
To measure the frequency of a signal, you have to display its waveform. To obtain this display, you will use internal triggering and the automatic triggering mode. Set the TRIGGER SLOPE control to -INT (4). With this setting, you won't need external triggering connections. Set the TRIGGERING MODE control to AUTO (5). This will give you a stable display without having to adjust any of the triggering controls.

2.28

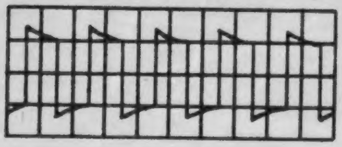
With the TRIGGER SLOPE control at -INT, and the TRIGGERING MODE at AUTO, the sweep will free-run until an input is applied at the vertical input. The sweep will then be triggered by the negative portion of the vertical input signal. The speed of the sweep will still be controlled by the setting of the TIME/CM control.



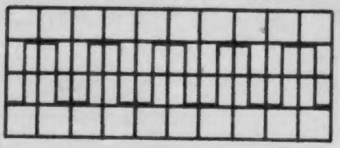
	2.29 You are now ready to calibrate your instrument. To calibrate the sweep speed or TIME/CM, move the (red) VARIABLE control to its extreme clockwise position, thus extinguishing the UNCALIBRATED light (6) (7).
	2.30 With the VARIABLE TIME/CM control fully clockwise, the sweep speed is __________.
calibrated	**2.31** A compensation may have to be made in the 10X probe so that it does not distort the waveshape, thus causing errors in the measurement of __________. We will next describe how to check and adjust your probe.
frequency	**2.32** Adjust the INTENSITY and FOCUS so that the line is visible and sharp (8). Now connect the probe to CHANNEL __________ of the CA Plug-In Unit. Next set the AMPLITUDE CALIBRATOR to 5 volts (9). With the VOLTS/CM control at .2, the signal will be displayed in 2 CM. Connect the probe tip to the CAL OUT jack, with your right hand on the shaft, just behind the tip (10). Do not touch the tip.



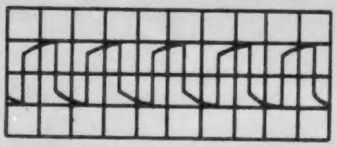
OVER COMPENSATED



ADJUSTED CORRECTLY



UNDER COMPENSATED



B

2.33

With your left hand, turn the raised portion of the probe, behind the center ring, two full turns counter-clockwise. This unlocks the probe for adjusting. Hold the rear of the probe in your left hand and turn the front portion (ahead of the ring) with your right hand, in whatever direction is necessary to obtain perfect square waves. Use the lower figure on the left as a guide. The probe is now __________.

compensated
(adjusted)

2.34

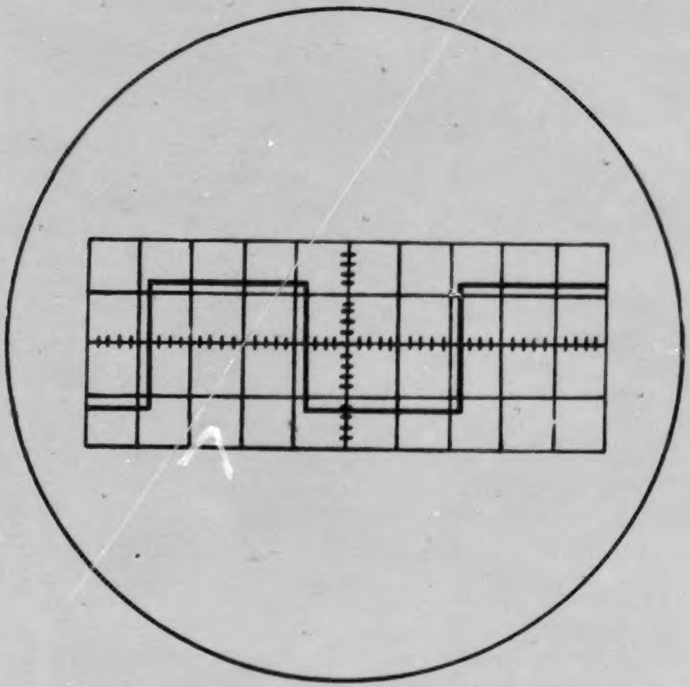
Without changing the setting of the front portion, turn the raised portion at the rear clockwise, until it is finger tight. You are almost ready to display the signal. If the tip of the probe is not fitted with a banana plug, attach one now. To protect the scope and provide a reference point for the signal, you must attach a ground wire from any of the **ground points** on the 545A to the ground of the signal to be measured. See upper figure at the left.

2.35

Attach the ground lead to Jack G of the Signal Generator and make certain that the Function Switch of the Signal Generator is in Position 5. Now plug the probe into Jack A of the Signal Generator. You should see a square wave about 2 1/2 centimeters high.

2.36

If the display is not on the screen, look at the vertical position indicators and move the VERTICAL POSITION control of CHANNEL __________ until both lamps are __________. If the trace is still not visible, increase the intensity.



51

B

extinguished (out)

2.37

The signal displayed on the screen should be at least one complete cycle. If you have less than one cycle, your sweep is too fast. You should move the TIME BASE A TIME/CM control counter-clockwise to a slower sweep speed.

2.38

You should not have much more than 2 cycles displayed. If you do, your sweep is too slow and you should move the TIME/CM control __________ to a __________ sweep speed.

clockwise

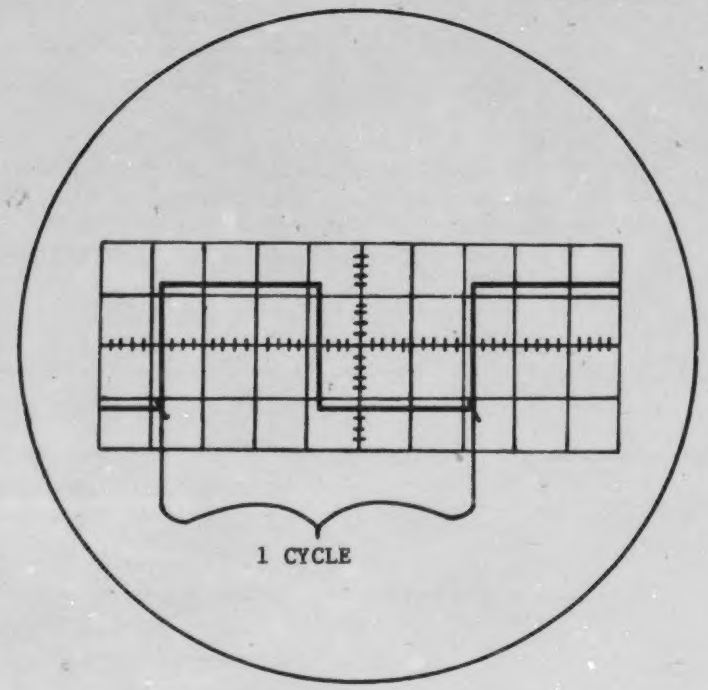
faster

2.39

Adjust the TIME/CM control so that you have at least one complete cycle of the signal displayed. The figure on the left is an example. It shows over 1-1/2 cycles. Your display will be wider or narrower, but it should show at least one full cycle.

2.40

To determine the frequency of the signal, you will count the number of centimeters which one cycle of the display covers horizontally.


1 CYCLE

2.41

The more accurately you can count the number of centimeters covered by one cycle of the signal, the more accurate your measurement of frequency will be. Therefore, use the HORIZONTAL and VERTICAL POSITION controls to align your display with the grid as shown in the figure.

2.42

You are now ready to evaluate your display. Starting at the left, one square-wave cycle includes:

a. Rise	c. Fall
b. Duration at high level dc	d. Duration at low level dc

Now count the number of centimeters horizontally (from left to right), starting with the beginning of the first rise and ending with the beginning of the next rise.

2.43

If you are still uncertain about how to count the distance covered by one cycle, look at the figure. Count the number of centimeters between the "/" marks, as these marks show the beginning and end of one cycle.

2.44

Now look at your display and count the number of centimeters covered by one cycle of the square wave. One cycle covers _______ centimeters.

2 or 4 or 8,
depending on your
TIME/CM Setting

2.45 If your TIME/CM setting is:

a. 2 milliseconds, one cycle covers 2 centimeters.
b. 1 millisecond, one cycle covers 4 centimeters.
c. .5 millisecond, one cycle covers 8 centimeters.

Knowing the sweep speed and the number of centimeters covered by one cycle, it is possible to calculate the frequency.

2.46 To find the frequency in cycles per second, solve:

$$\text{frequency} = \frac{1}{(\text{number of CM}) \times (\text{TIME/CM Setting})}$$

with TIME/CM Setting given in seconds.

Example: 1 millisecond = .001 seconds.

2.47

For this example, we will use the TIME/CM Setting of 1 millisecond or .001 seconds. The number of CM for 1 cycle is 4, so,

$$\text{frequency} = \frac{1}{(4\text{CM}) \times (.001 \text{ seconds})}$$

2.48

$$\frac{1}{(4\text{CM}) \times (.001 \text{ seconds})} = .004\overline{)1.000} \text{ or}$$

250. The frequency of this signal is _____ cycles per second.

250	**2.49** If we had used a TIME/CM setting of .5 milliseconds, or .0005 seconds, with 1 cycle covering 8 CM, we would have had: frequency = $\frac{1}{(8\ \text{CM}) \times (.0005\ \text{sec.})}$ or $.004\overline{)1.000}$ The frequency would still be _____ cycles per second. Remove the probe from the Signal Generator.
250	**2.50** To measure an unknown frequency, you would set the TIME/CM control at the middle of its range, or ______ milliseconds. After obtaining a display, you would adjust the TIME/CM control so that you have at least ______ complete cycle on the screen.
.5 1 (one)	**2.51** You would position the display so that the beginning of one cycle is aligned with one of the vertical grid lines. You would then _____ the number of centimeters from the beginning of one cycle to the beginning of the next.
count (determine)	**2.52** Using the setting of the ____/_____ control, expressed in seconds, and the number of ______ covered by 1 cycle of the display, you would calculate the frequency.

EXAMPLE	CENTIMETERS	TIME/CM SETTING	1/PRODUCT=CPS	
1	4	1 MILL- SEC.	$\frac{1}{.004}$	250
2	2	2 MILL- SEC.	$\frac{1}{.004}$	250
3	2	1 MILL- SEC.	$\underline{1}$	
4	4	.5 MILL- SEC.		
5	3	10 MILL- SEC.		

TIME/CM

centimeters (CM)

2.53

The frequency is given in ______ per ______ when the TIME/CM control setting is expressed in ______ and the horizontal distance covered by one cycle is expressed in ______.

cycles second

seconds

centimeters (CM)

2.54 Look at the figure on the left. Examples 1 & 2 are worked out for you. Using the formula,

$$\text{frequency} = \frac{1}{(\text{CM}) \times (\text{TIME/CM Setting in seconds})}$$

work out the frequency of examples 3, 4, and 5. Write the answers on your Response Sheet.

3. 500 cps
4. 500 cps
5. 33.3 cps

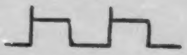
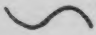
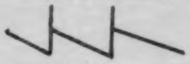
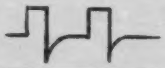
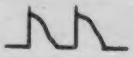
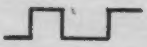
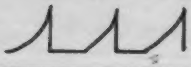
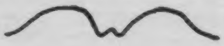
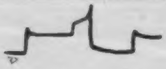
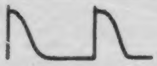
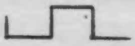
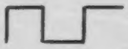
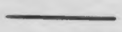
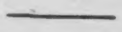
2.55

To set up the scope to display a known frequency, you could use the formula for frequency to find the TIME/CM setting to use.

2.56 The formula would be:

$$\text{TIME/CM} = \frac{1}{(\text{CM}) \times (\text{frequency})}$$

Let's say we want to look at a signal whose frequency is 500 cps, and we want 1 cycle to cover 4 CM.

FUNCTION SWITCH	JACK	VOLTS	FREQUENCY	PATTERN
1	A	—	—	
2	B	—	—	
3	A	—	—	
4	A	—	—	
4	B	—	—	
5	A	5	250 cps	
5	B	200	—	
6	A	—	—	
8	A	—	—	
8	B	—	—	
9	A	—	—	
9	B	—	—	
10	A	DC	ZERO	
10	B	DC	ZERO	

2.57

You would use 4 CM and 500 cps to obtain the TIME/CM Setting, by solving:

$$\text{TIME/CM} = \frac{1}{(4\ \text{CM}) \times (500\ \text{cps})}$$

This would be 1/2000 or .0005 sec. You would set the TIME/CM control at _____ millisecond(s).

.5

2.58

With the TIME/CM control in the .5 millisecond position and the VARIABLE TIME/CM control in the _____ position, each cycle of a 500 cps signal would cover ______CM.

CALIBRATED

4

2.59

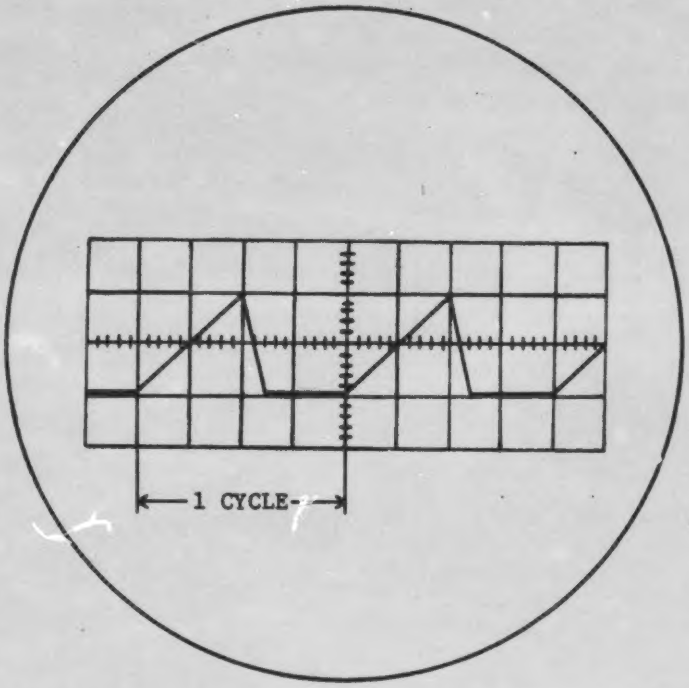
Let's try one more frequency measurement. Put the Function Switch of the Signal Generator in Position 1. We will measure the frequency of the signal at Jack A. Look at the figure at the left. Notice that the waveshape is given but both the voltage and frequency are unknown.

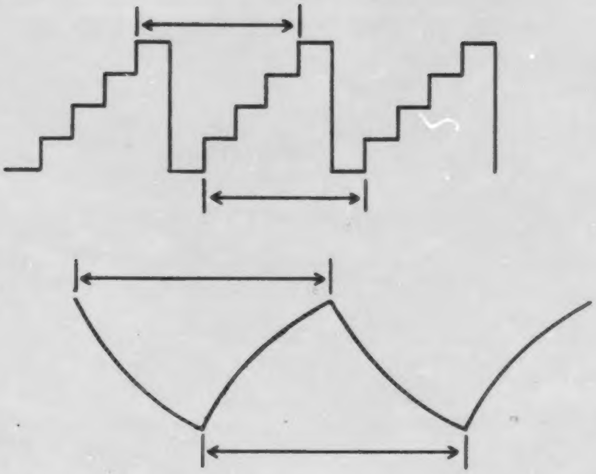
2.60

Your problem has been defined and your equipment is assembled, turned on, and checked out. You will now _____ the controls, beginning with the vertical section, or Type CA ______ ______ Unit.

preset Plug-In	**2.61** You may select either vertical input for this problem. Select one now, using the _____switch. You must next set the VOLTS/CM control. Because the voltage is not given, you would set the control in the extreme counter-clockwise position or in the _____ volts position. This is done to protect the scope.
MODE 20	**2.62** Move this control now. You will now select and set the _____ Base controls. Please use TIME BASE A again. Check to see that the HORIZONTAL DISPLAY control is in the _____ position.
Time A	**2.63** To insure an initial trace, set the TRIGGERING MODE to _____ and the TRIGGER _____ to -INT.
AUTO SLOPE	**2.64** Set these controls now. The last control to be preset is the _____/_____ control of TIME BASE A. Since the frequency is unknown, set the control at the _____ _____ position, or the middle of its range.

TIME/CM .5 milliseconds	**2.65** Set this control now. When making frequency measurements, always make sure that the VARIABLE section of the TIME/CM control is in the __________ position. Before obtaining your display, check again to see that the trace is centered; if not, center it, using the four ________ ________ lamps as guides.
CALIBRATED position indicator	**2.66** Now connect your probe to the selected vertical input channel and to Jack A of the Signal Generator. You will probably not see a signal at this point; so begin turning the VOLTS/CM control in a clockwise direction and continue this until your display is about 2 CM high.
	2.67 To measure frequency you must have at least __________ cycle of the signal showing on the scope. With the TIME/CM control set at .5 milliseconds, if you have more than 2 cycles, your sweep speed is too __________.
1 (one) slow	**2.68** To increase the sweep speed, move the TIME/CM control ______ to a setting which gives you less than 2 but not less than 1 cycle on the scope.


1 CYCLE



clockwise	2.69 If you have less than 1 cycle showing on the oscilloscope, your sweep speed is too ______ and you must move the TIME/CM control _____ - _______ to a setting which gives you more than 1 cycle displayed on the screen.
fast counter-clockwise	2.70 Now adjust the ______/______ control until you have at least one complete cycle displayed. To measure frequency you must count the number of ______ covered by 1 cycle of the signal along the horizontal dimension, that is, from left to right.
TIME/CM centimeters (CM)	2.71 To help you do this accurately, pick a point on the left side of the waveform which is easily identified and align this point with one of the vertical grid lines, using the HORIZONTAL POSITION control. See the figure on the left for some examples of easily identified points on different waveshapes.
	2.72 Now starting at the grid line aligned with the point on the wave, count the number of _____ covered by one cycle of the signal. Write this number on your Response Sheet.

TIME/CM Setting	Equivalent In Seconds
Sec.	
5	5
2	2
1	1
.5	.5
.2	.2
.1	.1
Millisec.	
50	.05
20	.02
10	.01
5	.005
2	.002
1	.001
.5	.0005 (5×10^{-4})
.2	.0002 (2×10^{-4})
.1	.0001 (10^{-4})
Microsec.	
50	.00005 (5×10^{-5})
20	.00002 (2×10^{-5})
10	.00001 (10^{-5})
5	.000005 (5×10^{-6})
2	.000002 (2×10^{-6})
1	.000001 (10^{-6})
.5	.0000005 (5×10^{-7})
.2	.0000002 (2×10^{-7})
.1	.0000001 (10^{-7})

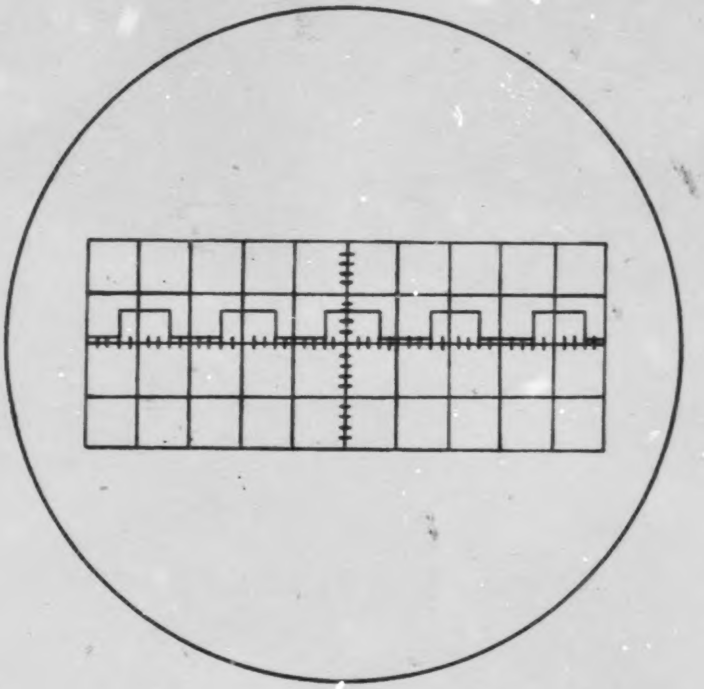
CM (Use your answer in this frame)	2.73 Multiply the number of CM covered by 1 cycle of the wave by the setting of the ______/_______ control in seconds (the conversion factors are shown on the left) and divide your answer into 1.0. This will give you the frequency. Write the answer on your Response Sheet.
TIME/CM 250 cps	2.74 If you did not get 250 cps for the answer, go back and check your setting of the Signal Generator and the scope controls; also check your arithmetic.
	2.75 If you have the correct answer you are doing very well. This completes the section on measurement of frequency and we are now ready to begin the measurement of voltage.
	2.76 Continue the Program.

PART C

THE MEASUREMENT

OF

VOLTAGE



3.1

Now that you have learned how to measure frequency, we will take up the measurement of voltage. There are three basic types of voltage measurements which can be made with the 545A: peak-to-peak, dc level, and instantaneous dc voltage.

3.2

In defining your problem you must determine whether you are going to make ac measurements, dc measurements, or both. In the first problem, you will be measuring peak-to-peak ac voltage.

3.3

Your problem is to measure the output voltage at Jack A of the Signal Generator when the Function Switch is in Position 5. Look at the figure on the left. This is an example of the signal you will be measuring.

3.4

The equipment required for this problem is the same equipment you used for the problems of frequency measurement.

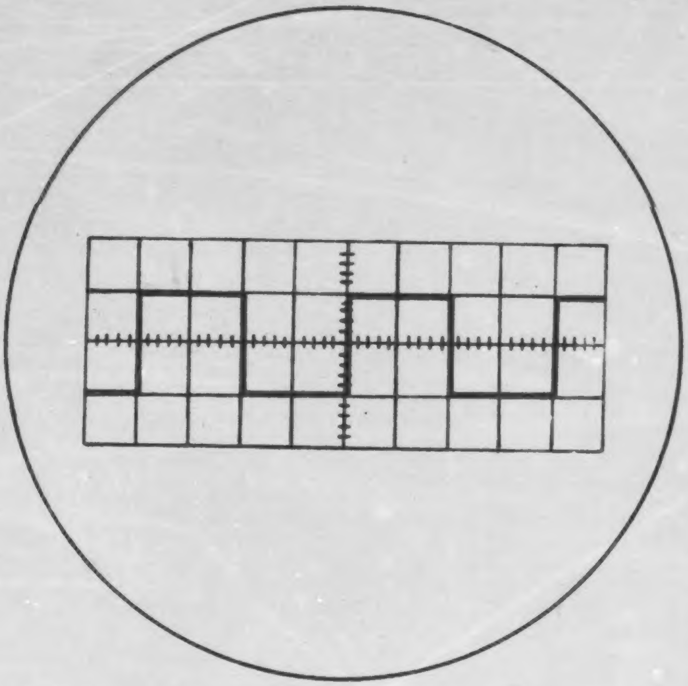
	3.5 You will need the 545A Oscilloscope with a Type _____ Plug-In Unit and a Type P-6000 or P-6006 probe. The probe has an attenuation factor of _______.
CA 10 (10X)	3.6 Now that you have defined your problem and assembled equipment, the next step is to turn on and _______ ______ the scope.
check out	3.7 If your scope is on from the previous section, you need not turn it off and start over. If your scope is off turn it on, following the correct procedures. If you have any doubts about the correct procedures, refer to Frames 1.29 thru 1.52.
	3.8 Now you must preset and calibrate it. Please use TIME BASE A and CHANNEL A for this problem. You select TIME BASE A using the ______ _______ switch and CHANNEL A using the _____ switch.

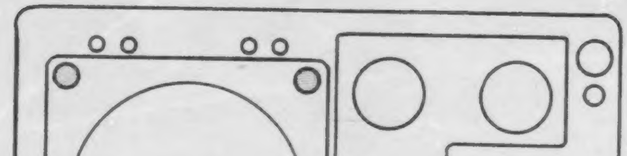
	3.9 The setting of the Time Base controls is not critical when measuring voltage; all that is required is to set the controls so that you will get an initial display.
HORIZONTAL DISPLAY MODE	
	3.10 You learned earlier that you will almost always get an initial display by setting the TRIGGERING MODE to _____ and the TRIGGER SLOPE to + or - ______.
AUTO INT.	3.11 Since the setting of the Time Base controls is not critical, a good setting for the TIME/CM control is ______ ______, or the middle of its range.
.5 millisec.	3.12 Voltage is measured by counting the number of CM of vertical deflection. The amount of the vertical deflection is controlled by the setting of the ______/CM control of the correct channel of the CA Plug-In Unit.

VOLTS	3.13 The settings of the VOLTS/CM control range from ______ to ______ volts. Notice the red _____ control. When the VARIABLE control is all the way clockwise, it is in the CALIBRATED position.
20 .05 VARIABLE	3.14 All voltage measurements must be made with the VARIABLE VOLTS/CM control in the CALIBRATED position. Rotate the VARIABLE VOLTS/CM control back and forth and then set it in the CALIBRATED position.
	3.15 When the CHANNEL A VOLTS/CM control is in the 20 volts position, you will get 1 CM of vertical deflection for each _____ volts applied at the input of CHANNEL A.
20	3.16 Assume that the VOLTS/CM control is set at 20, and 40 volts is applied at the input. The vertical deflection would be ______ (how many) CM.

2	**3.17** Now assume that the VOLTS/CM control is at .5. How many volts would you have to have at the input to get a deflection of 2 CM? _____ volt(s).
1.0	**3.18** The probes you are using have an attenuation factor of ______. This means that if a 50-volt signal is applied to the probe tip, the voltage at the input to the scope will be reduced by a factor of 10 and the signal at the input of the scope will be 50/10, or ______ (how many) volts.
10 (10X) 5	**3.19** With 10X probes, if you wanted the display of a 50-volt signal to be 1 CM high, you would set the VOLTS/CM control at ______.
5	**3.20** Suppose you were to measure a 100-volt signal at the probe tip. Your signal at the input to the scope would be _____ (how many) volts. If you wanted a display of 2 CM, you would set the VOLTS/CM control in the _______ position.

10 5	3.21 Now that you understand the attenuation of the probe and how to set the VOLTS/CM control, we will finish presetting and calibrating the instrument. Set the CHANNEL A VOLTS/CM control to .5. Make sure the VARIABLE VOLTS/CM control is in the ______ position.
CALIBRATED	3.22 Now set the AMPLITUDE CALIBRATOR to 10 volts. Connect a probe to the CHANNEL A input. When you touch the probe to the CAL OUT jack, you should see a square wave on the screen which is _______ (how many) CM high.
2	3.23 Remember the 10-volt signal at the CAL OUT jack will be only a 1-volt signal at the CHANNEL A input. Since .5 volts will give 1 CM of deflection, 1 volt will give 2 CM of deflection.
	3.24 Before you count the number of CM of vertical deflection, you must make sure your probe is compensated correctly. Touch the probe tip to the CAL OUT jack, now. If the trace goes off the screen, it is up to you to reposition it within the limits of the grid. If the waveshape is distorted, you will not be able to make accurate measurements. Adjust your probe as described in Frames 2.31 to 2.34.





3.25

Your display should look something like that on the left. To measure voltage you should have at least 2 or 3 cycles of the wave displayed, so that you can identify the lowest and highest points of the wave. To obtain more or fewer cycles displayed, you change the setting of the TIME/CM control of the correct Time Base.

3.26

Now measure the vertical size of the square waves, from the lower voltage to the higher voltage. See the figure on the left. Your display should be _____ CM high.

2

3.27

It is possible that your display will not be exactly 2 CM high. This would happen if CHANNEL A were out of adjustment internally. If your display is not exactly 2 CM high, make a note of it and go on; do not try to correct it.

3.28

You have now finished presetting and calibrating your scope and probe for voltage measurements. Take the probe away from the CAL OUT jack. Before you connect the probe tip to Jack A of the Signal Generator, make sure you have a ground connection between Jack G and the **ground points** on the scope.

3.29

Now make sure the Function Switch of the Signal Generator is set at Position 5. Insert the banana plug on the tip of the probe into Jack A of the Signal Generator.

3.30

Determine the height of the waveform at Jack A. The display is __________ (how many) CM high.

1

3.31

Peak-to-peak voltage is determined by the formula:

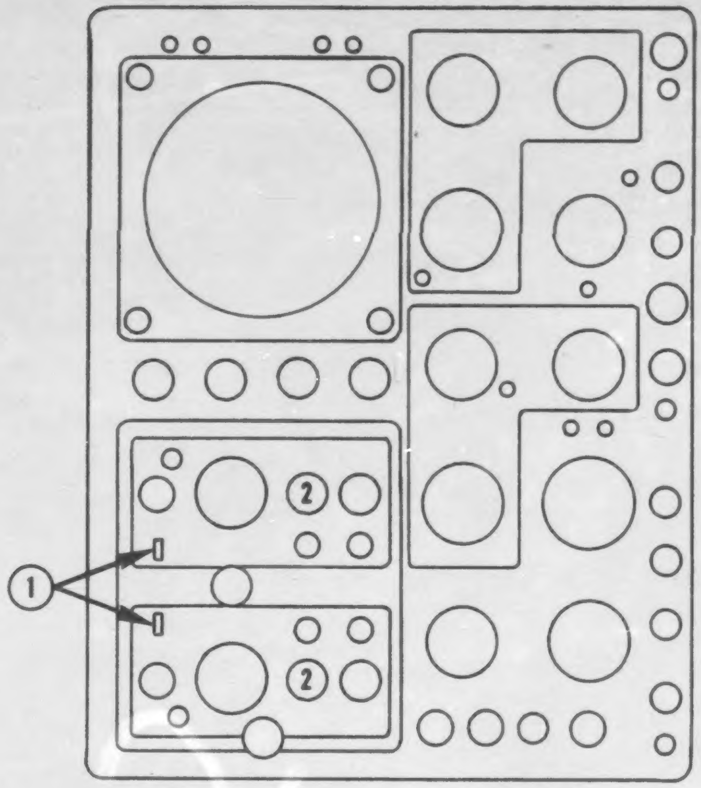
V_{p-p} = Height (CM) x Probe Atten. x VOLTS/CM Setting

In this case the height is 1 CM so the voltage is:

V_{p-p} = 1 x 10 x .5 = 5 volts.

3.32

The peak-to-peak voltage of the signal at Jack A of the Signal Generator is __________ volts.



5

3.33

Before we go on to another measurement, there are two controls on the CA Plug-In Unit that we have not discussed yet: the AC-DC switch and the POLARITY switch (1) (2).

3.34

The AC-DC switch determines whether the input is direct or capacitive coupled (1). The standard preset position for this switch is DC. However, if a signal has a dc component which should be removed, this switch should be put in the AC position. If this switch is not in the AC position, put it there now.

3.35

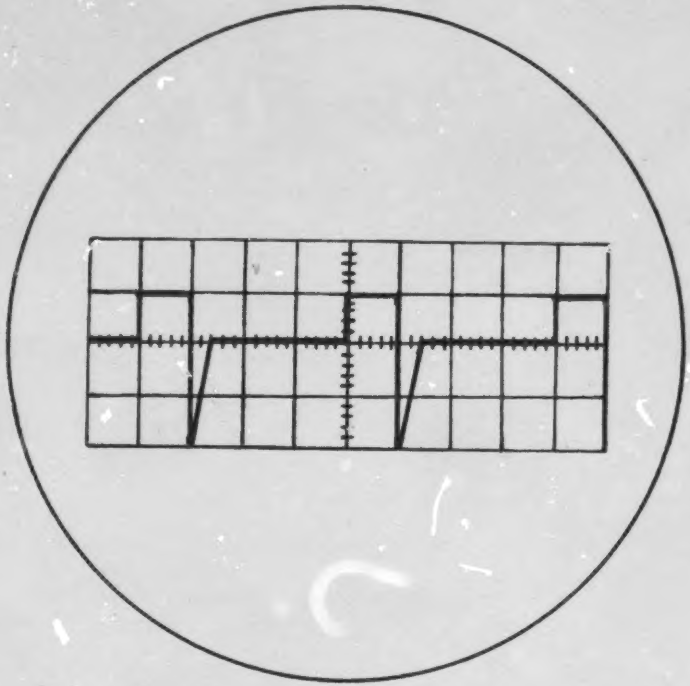
Before we continue, remove the probe from Jack A of the Signal Generator and set the VOLTS/CM control to .2. Touch the probe to ground and position the reference (or no-signal) line on the center grid line.

3.36

Now touch the probe tip to Jack A of the Signal Generator several times while watching the screen. The square wave goes __________ and below the reference line by equal amounts. This is because we have removed the dc component of the signal by putting the AC-DC switch in the AC position. Now remove the probe from Jack A and move the AC-DC switch to DC.

above	3.37 Again touch the probe to Jack A of the Signal Generator several times. Make sure the POLARITY switch is in the NORMAL position. This time the square wave goes __________ from the no-signal or __________ line.
down reference	3.38 When a signal goes down from the reference line, it is called a "negative-going signal." It is usually easier to measure signal voltage when the signal rises from the reference line. Now move the POLARITY switch to the INVERTED position.
	3.39 Again touch the probe to Jack A several times. With the POLARITY switch in the __________ position, the square wave rises from the __________ line.
INVERTED reference	3.40 Now touch the probe tip to ground and align the reference line with the bottom grid line. Plug the probe into Jack A of the Signal Generator. The square wave is now __________ CM high.

2.5 (2 1/2)	3.41 The voltage of the square wave is: V_{p-p} = Height (CM) x Probe Atten. x VOLTS/CM Setting The VOLTS/CM setting is ________. Therefore the V_{p-p} is ________ volts.
.2 5	3.42 This is the same voltage you obtained before, but now we know the polarity of the signal. Remember that with the POLARITY switch in the INVERTED position, a negative-going signal will ________ from the reference line.
rise	3.43 When measuring unknown voltages, always start with the VOLTS/CM control in the extreme counter-clockwise or ________ position, to protect the scope.
20	3.44 Now put Switch FS1 of the Signal Generator in Position 4. Put the POLARITY switch in the NORMAL position. Ground the probe tip and place the sweep line on the center line of the grid.



3.45

Now connect the probe to Jack A of the Signal Generator. Rotate the VOLTS/CM control clockwise until you can see the waveshape within the limits of the grid. Remove your probe from Jack A and, with the probe grounded, center the sweep line.

3.46

Now touch your probe tip to Jack A. This waveshape is __________-going because it falls below the reference line when the POLARITY switch is in the NORMAL position.

negative

3.47

Now remove the probe from Jack A and put it in Jack B. This wave is a __________-going signal.

positive

3.48

Now place the AC-DC switch in the AC position. Connect your probe to Jack A of the Signal Generator. Position the display so that the lowest point on the wave rests on one of the horizontal grid lines as shown in the figure at the left.

3.49

Now determine the height of the waveform in CM and calculate the voltage.

V_{p-p} = Height (CM) x Probe Atten. x VOLTS/CM Setting

Write the answer on your answer sheet. Without moving any controls, connect your probe to Jack B and calculate the voltage for this signal.

3.50

The V_{p-p} of the signal at Jack A (is/is not) __________ the same as the signal at Jack B. The voltages of the signals are __________ and __________ volts.

is

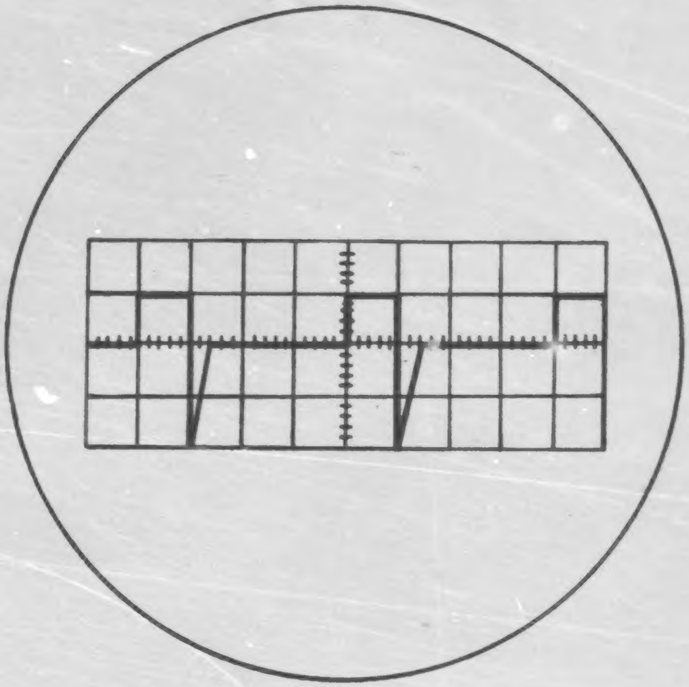
10.5 10.5

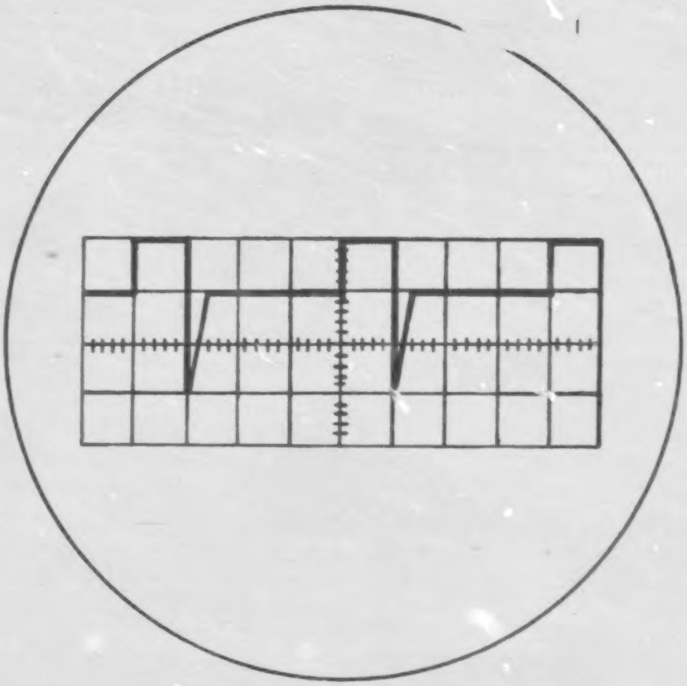
3.51

To measure a dc level, set the AC-DC switch in the DC position. Now set the VOLTS/CM control to 20. Ground the probe tip and set the reference line on the bottom line of the grid.

3.52

Connect the probe tip to the signal source. In this case it is Jack A of the Signal Generator. Turn the VOLTS/CM control clockwise until you see the sweep line move from the reference level or the signal appear. Now remove the probe from the signal source and check the position of the reference line by grounding the probe tip; reposition if necessary.





3.53

Touch the probe tip to the signal source (Jack A) and note the direction of movement of the trace. Set the POLARITY switch so that the trace rises from the ______ line. Now set the VOLTS/CM control so that you get maximum upward movement of the trace, without having any portion of the display outside of the grid lines.

reference

3.54

Now set the AC-DC switch to AC and connect the probe to the signal source. Position the display so that the lowest point of the signal is on the bottom grid line. See the upper figure. Now switch the AC-DC switch to DC.

3.55

The trace moves ______ from the bottom grid line. To determine the dc level, count the number of CM that the lowest point of the waveform has risen. This is the point that was on the bottom ______ line. See the lower figure.

up (upward)

grid

3.56 Use this CM reading in the voltage calculation:

V_{DCL} = CM (fr. grid line) x Probe Atten. x VOLTS/CM Setting

The lowest point on the wave moved ______ CM from the bottom grid line. The dc level of the signal is _____ volts. Remember the setting of the POLARITY switch, as dc levels are either + or -.

1.1 -5.5	**3.57** Let's review a minute. Time Base control settings are not critical when measuring voltages, except to provide a stable display of 2 or 3 cycles. To begin, you would set the TRIGGERING MODE to ____ and the TRIGGER SLOPE to + or - _____. The TIME/CM control would be set to _____ millisec., the middle of its range.
AUTO INT. .5	**3.58** After obtaining the display, you would obtain 2 or 3 cycles of the wave form by adjusting the ____/_____ control.
TIME/CM	**3.59** To measure the peak-to-peak voltage of an ac signal, you set the AC-DC switch to ____ and the POLARITY switch to _____. Next, to protect the scope when measuring unknown voltages, you set the VOLTS/CM control to _____.
AC NORMAL 20	**3.60** You connect the probe to the signal source and turn the VOLTS/CM control _____ until you have a display which is as large as it can be without going outside the limits of the grid.

clockwise	3.61 You then align the lowest point of the wave with one of the horizontal grid lines and count the number of ______ vertically covered by the wave. To calculate the peak-to-peak voltage of the signal, you need to know the height of the wave, the probe ____, and the ____/_____ setting.
CM atten. (attenuation) VOLTS/CM	3.62 To determine the dc level of a signal, you set the POLARITY switch so that the trace will _____ from the bottom _____ line as you turn the VOLTS/CM control, with the AC-DC switch in the _____ position.
rise grid DC	3.63 You then position the display, with the AC-DC switch in _____, so that the lowest point of the signal is at the bottom grid line. Then you put the AC-DC switch in _____. You count the number of _____ the point you selected rose above the bottom grid line.
AC DC CM	3.64 To calculate the dc level in terms of volts, you use the same formula you used for peak-to-peak voltage, only instead of using the height, you use the vertical distance that the selected point moved above the bottom _____ line.

grid

3.65

There is one other type of voltage measurement you can make. This is the measurement of instantaneous dc voltage (V_I). The initial settings for this type of measurement are the same as for other type, except that the AC-DC switch is in the DC position. The POLARITY switch is set at ______. The VOLTS/CM control is set at _____.

NORMAL

20

3.66

Connect the probe to the signal source. In this case the source is Jack B of the Signal Generator. Now turn the VOLTS/CM control until you see the signal, or the sweep line moves from the reference level.

3.67

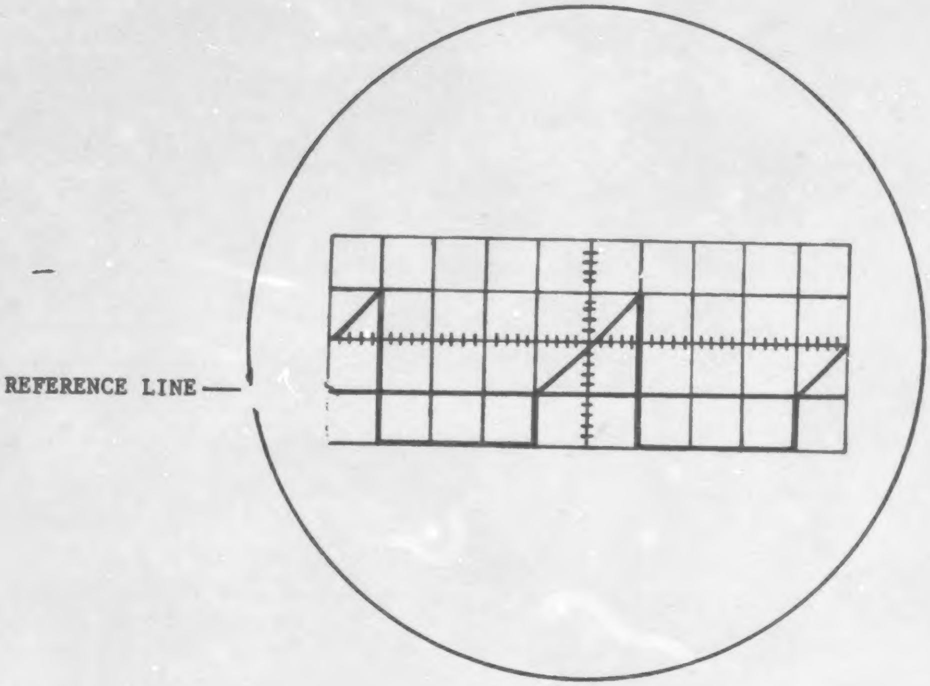
Determine whether the signal is positive-or negative-going and set the _____ switch so the trace rises from the reference line. Set the ______/_____ control so that the display is as large as possible without being outside of the grid lines.

POLARITY

VOLTS/CM

3.68

Now remove the probe from the signal source. As you do, look at the sweep line to see whether the signal was above or right on the no-signal sweep line.


REFERENCE LINE

3.69

Now ground the probe tip and position the no-signal or reference line. If the signal was above the no-signal sweep line, position the reference line on the __________ grid line. If the signal was right on the sweep line, position the __________ line on the middle line of the grid.

bottom

reference

3.70

Now reconnect the probe to the signal source (Jack B of the Signal Generator). With the signal displayed, you can determine the absolute maximum and minimum signal voltages.

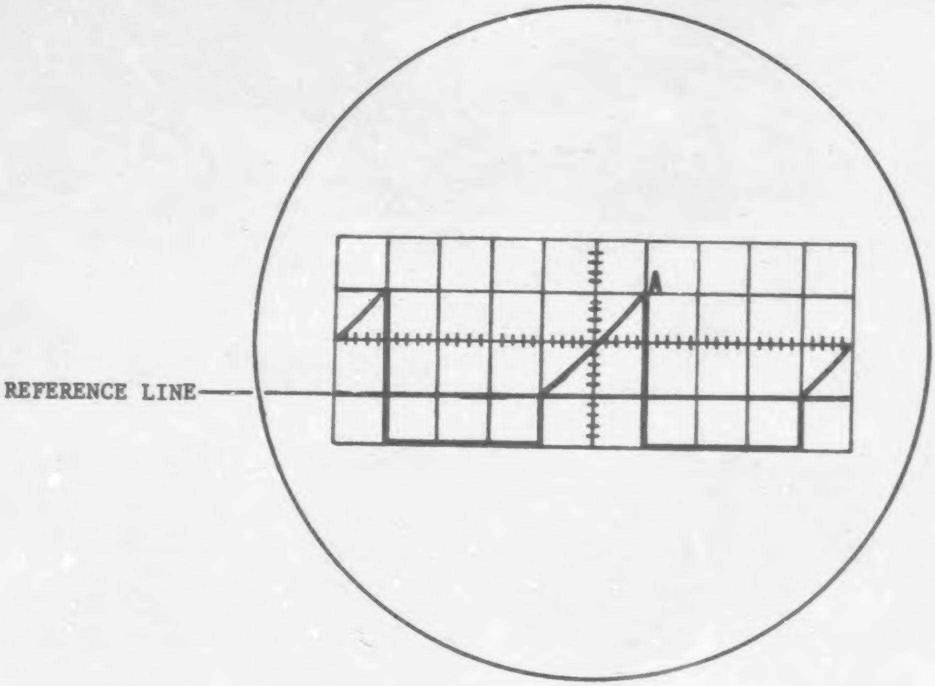
3.71

Remember that if both the maximum and the minimum voltage points are above the reference line, both voltage levels will be either + or - depending on the setting of the __________ switch.

POLARITY

3.72

If the signal varies both above and below the reference line, there will be a maximum positive level and a maximum negative level. One of these components, either the positive or the negative, may be larger than the other. Look at the figure on the left.


REFERENCE LINE

	3.73 Suppose the POLARITY switch were in the INVERTED position. The peak at A would be a _____ (polarity) peak. The peak at A would be a positive voltage only if the POLARITY switch were in the _____ position.
negative NORMAL	3.74 When measuring voltage levels, the sign (+ or -) of the voltage depends upon the direction of deflection (up or down) from the reference line and the setting of the _____ switch.
POLARITY	3.75 Set FS1 of the Signal Generator to Position 3. Measure the peak-to-peak voltage of the signal at Jack A with the AC-DC switch in the ______ position. V_{p-p} = ________
AC 10.5 volts	3.76 Now measure the maximum and minimum voltages of the same signal with the AC-DC switch in the ____ position. Don't forget about the polarity. V_I = ________ and ________

DC

+9 and -2 volts

3.77

If you got both of these correct, you are doing very well. This concludes the section on measurement of voltage.

Continue the program.

PART D

DUAL TRACE

OPERATION

BEFORE PROCEEDING WITH SECTION IV, YOU WILL FIND A SHORT, NINE-FRAME REVIEW OF WHAT YOU HAVE LEARNED. INDICATE YOUR ANSWER BY PLACING A CHECK IN THE BLOCK PROVIDED ON THE RESPONSE SHEET FOR EACH REVIEW FRAME. AFTER YOU HAVE SELECTED YOUR ANSWER, SEE IF YOU MADE THE CORRECT CHOICE BY CHECKING THE CONFIRMATION SECTION AT THE BOTTOM OF EACH REVIEW PAGE.

4.1

Which of these statements is/are true?

A	B
The selection of the two inputs to the Type CA Plug-In Unit is controlled by the MODE switch.	The amplitude or height of the display is determined in part by the setting of the VOLTS/CM control.

4.2

Selection of TIME BASE A is determined by positioning what control?

A	B
Type CA Plug-In Unit MODE switch.	VERTICAL POSITION control.

4.3

If you are instructed to use CHANNEL B and TIME BASE A, what adjustment(s) would you make?

A	B
MODE switch to B ONLY.	HORIZONTAL DISPLAY control to A.

CONFIRMATION: 4.1 Both 4.2 Neither 4.3 Both

4.4

Which is the correct TURN-ON PROCEDURE?

A	B
1. POWER switch "off".	1. POWER switch "off".
2. INTENSITY control counter-clockwise.	2. INTENSITY control clockwise.
3. Power cord into wall outlet.	3. POWER switch "on".
4. POWER switch "on".	4. Power cord into wall outlet.

4.5

Select the list containing the correct order of steps common to measurement problems.

A	B
1. Define your problem.	1. Turn on and checkout.
2. Turn on and checkout.	2. Assemble equipment.
3. Preset and calibrate.	3. Define your problem.
4. Assemble equipment.	4. Preset and calibrate.
5. Obtain and evaluate display.	5. Obtain and evaluate display.

4.6

You are calibrating your scope for voltage measurement and find that it is out of calibration. Which list(s) contain(s) probable causes?

A	B
VARIABLE on VOLTS/CM out of its CALIBRATED position.	VARIABLE on TIME/CM in UNCALIBRATED position.
GAIN ADJ. improperly adjusted.	HORIZONTAL DISPLAY in position B.

CONFIRMATION: 4.4 A 4.5 Neither 4.6 A

4.7 Which formula is used for measuring frequency with the 545A?

A	B
$\frac{1}{\text{CM x TIME/CM Setting}}$	CM x VOLTS/CM Setting

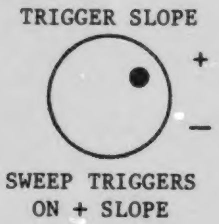
4.8 Which formula is used for measuring voltage with the 545A?

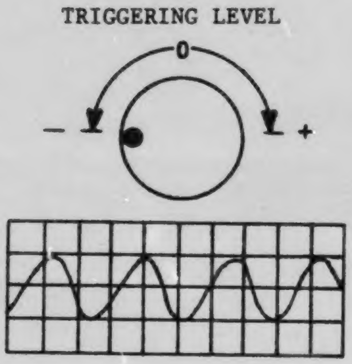
A	B
CM x TIME/CM Setting	CM x VOLTS/CM Setting x Probe Atten.

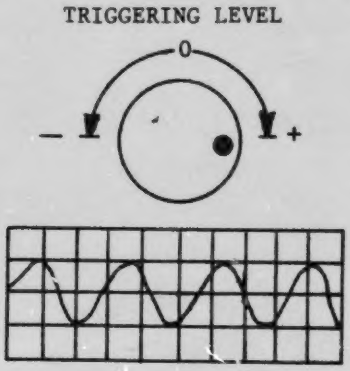
4.9 You wish to measure an unknown voltage from a test jack. Which list(s) contain(s) only correct presets?

A	B
INTENSITY fully CCW VOLTS/CM fully CCW POLARITY switch to NORMAL MODE switch to selected channel AC-DC switch to DC HORIZONTAL DISPLAY to selected time base 5X MAGNIFIER off TRIGGERING MODE to AUTO TRIGGER SLOPE to -INT TIME/CM to about .5 millisec. VARIABLE on TIME BASE A to CALIBRATED	INTENSITY fully CCW VOLTS/CM fully CCW MODE switch on Plug-In Unit to INT HORIZONTAL DISPLAY to DC TRIGGERING MODE to AUTO TRIGGER SLOPE to INT 5X MAGNIFIER off AC-DC switch to DC TIME/CM fully CCW VARIABLE on TIME BASE B fully CCW ASTIGMATISM fully clockwise SCALE ILLUM. off

CONFIRMATION: 4.7 A 4.8 B 4.9 A


TRIGGER SLOPE
+
–
SWEEP TRIGGERS
ON + SLOPE


TRIGGERING LEVEL
0
–
+


TRIGGERING LEVEL
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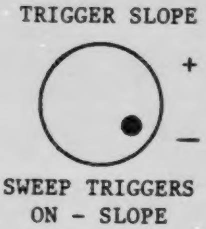
TRIGGER SLOPE
+
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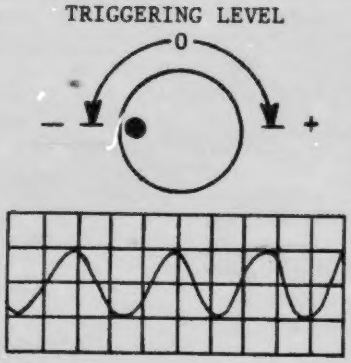
SWEEP TRIGGERS
ON - SLOPE


TRIGGERING LEVEL
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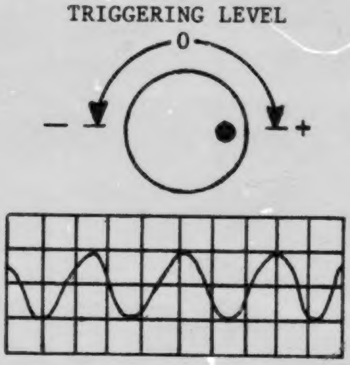
TRIGGERING LEVEL
0
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+

	4.10 Before we go on, there are two controls in the Time Base which we have not yet used. These are the STABILITY and TRIGGERING LEVEL controls. We have not used them because we have not used any TRIGGERING MODE other than ______.
AUTO	4.11 The STABILITY and TRIGGERING LEVEL controls have no effect when the TRIGGERING MODE switch is in AUTO. There are, however, four other triggering modes. Starting at the bottom and going clockwise, the TRIGGERING MODES, other than AUTO, are: ____ ____, ____ ____ REJECT, ____, and ____.
HF SYNC AC LF AC DC	4.12 With the TRIGGERING MODE switch in any of these four positions, you must use the STABILITY control and TRIGGERING LEVEL controls to obtain a stable display. The TRIGGERING LEVEL control sets the point on the rising or falling waveform where the sweep is to be triggered.
	4.13 Look at the figure on the left. Assume the TRIGGERING MODE is at AC and the TRIGGER SLOPE is at INT. When the SLOPE is + and the LEVEL is -, the sweep triggers on the lower portion of the rising part of the wave. Then turning the LEVEL control to + will make the sweep trigger on the ____ portion of the rising part of the wave. If the LEVEL control is left on the + side and the SLOPE is switched to -, the sweep will trigger on the ____ portion of the ____ part of the wave.

	4.14
upper upper falling	After setting the triggering point on the rising or falling waveform by using the TRIGGERING _____ _ control, you obtain a stable display by using the _____ control. The STABILITY control is usually left in the PRESET position (fully counter-clockwise).

	4.15
LEVEL STABILITY	Two of the triggering modes are very similar: the AC and AC LF REJECT modes. In the AC mode, triggering will occur on signals from 15 cycles to 5 mc. In the AC LF REJECT mode, reliable triggering cannot be obtained on signals having a frequency below 1000 cycles.

	4.16
	If you had a 60 cycle signal imposed on a 1500 cycle signal and you wished to trigger the sweep with only the 1500 cycle signal, would you set the TRIGGERING MODE to AC or to AC LF REJECT (pick one)?

	4.17
AC LF REJECT	The DC triggering mode provides triggering on signals from dc to 5 mc. The HF SYNC mode provides triggering for signals above 5 mc. Let's run through the procedure for adjusting the triggering controls for the modes other than AUTO.

	4.18 First you would select the triggering mode; let's say we are using the DC mode. Now select the triggering slope. We have been using either _____ or _____ INT.
+ -	4.19 You would next set the STABILITY control in its normal, or _____ position. Then with the ______ ______ control you can adjust the point on the rising or falling wave at which the sweep is triggered.
PRESET TRIGGERING LEVEL	4.20 If you do not get a stable display at this point, you will have to adjust both the STABILITY and LEVEL controls. Begin by moving both controls to their extreme clockwise positions.
	4.21 Now turn the STABILITY control counter-clockwise until the trace disappears from the screen. This is the correct setting for the STABILITY control. Now turn the LEVEL control counter-clockwise until a stable display appears.

	4.22 If the trace is not stable with the ______ control in the PRESET position, you have to adjust both the STABILITY and TRIGGERING LEVEL controls. However, the STABILITY control is normally left in the ____ position.

STABILITY PRESET	4.23 When it becomes necessary to display signals above 5 mc, the TRIGGERING MODE switch would be set to ______ ______. In this mode the TRIGGERING LEVEL control is not used to improve stability.

HF SYNC.	4.24 Starting at the PRESET position of the ______ control, you would rotate it clockwise until a display was obtained, and you would continue to adjust it until you had a stable display.

STABILITY	4.25 For most signals, the best starting point for the triggering controls is with the TRIGGERING MODE in _____ and the TRIGGER SLOPE in ____ or _____ _____. When using these settings, the _____ and ______ ______ controls are not used.

AUTO + - INT STABILITY TRIGGERING LEVEL	4.26 You now know how to measure voltage and frequency with the 545A. So far, what you have done could have been done with other instruments. Now you will discover some of the unique capabilities of the oscilloscope you are learning to operate. You will learn why the Type CA Plug-In Unit has two inputs and how they can be used.

	4.27 Turn your instrument off. Remove the power cable from the power source. Turn all controls with more than two positions completely counter-clockwise.

	4.28 You learned at the beginning of the program that there is an efficient way of proceeding to make measurements with the 545A. Review these steps by writing them out on your Response Sheet. The five steps of efficient use are: 1. ____________________. 2. Assemble ______________. 3. Turn on and ____________. 4. P_______ and C _________. 5. Obtain and ______ a display.

Define Your Problem Equipment Checkout Preset & Calibrate Evaluate	4.29 Turn the Function Switch of the Signal Generator to Position 5. Your next problem will be to compare, in voltage and frequency, two signals displayed at the same time.

4.30

You are reminded that, in this program, you are using the Type CA Plug-In Unit. For the problem ahead, you will need, in addition:

a. Two P-6000 or P-6006, 10 X probes.
b. One grounding line.

Assemble this equipment.

4.31

Now follow the proper turn-on procedure. As you do each step, write it down (tell what you did) and when you have finished, check what you did against the figure on the back of this page. Make any necessary corrections.

(Check your settings against the list on the back of this page before going on.)

4.32

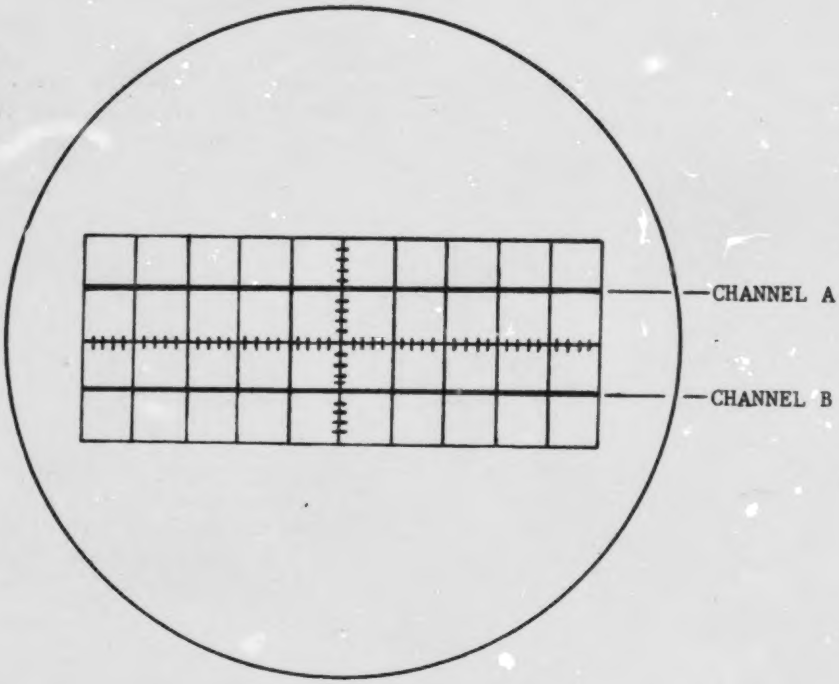
You must now preset and calibrate the instrument. Since you are going to compare two signals, you will need to use two input channels, each with a properly compensated probe.

4.33

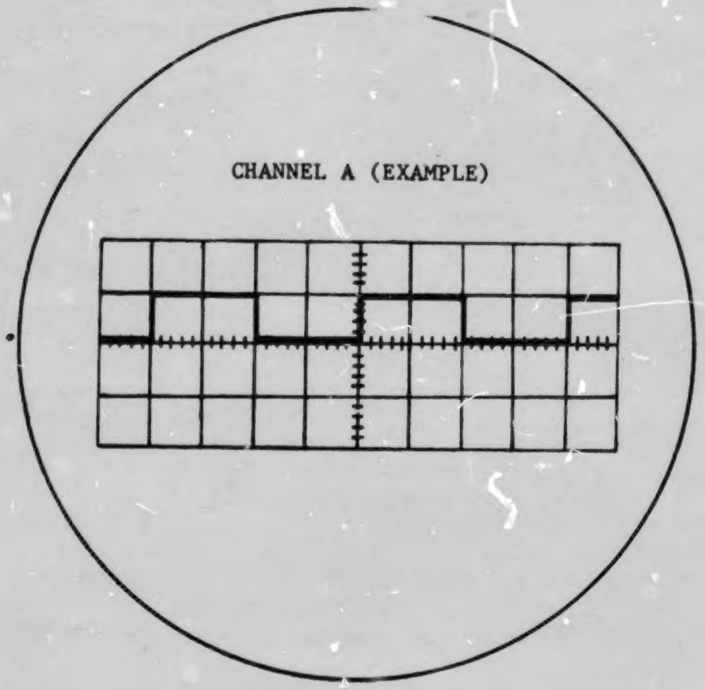
Connect one probe to each channel. Next you are to compensate each probe, starting with the one connected to CHANNEL A. Set the MODE switch of the Plug-In Unit to ______ ______. You will need at least a 2 CM display of the square wave at the _____ _______ jack.

TURN ON PROCEDURE

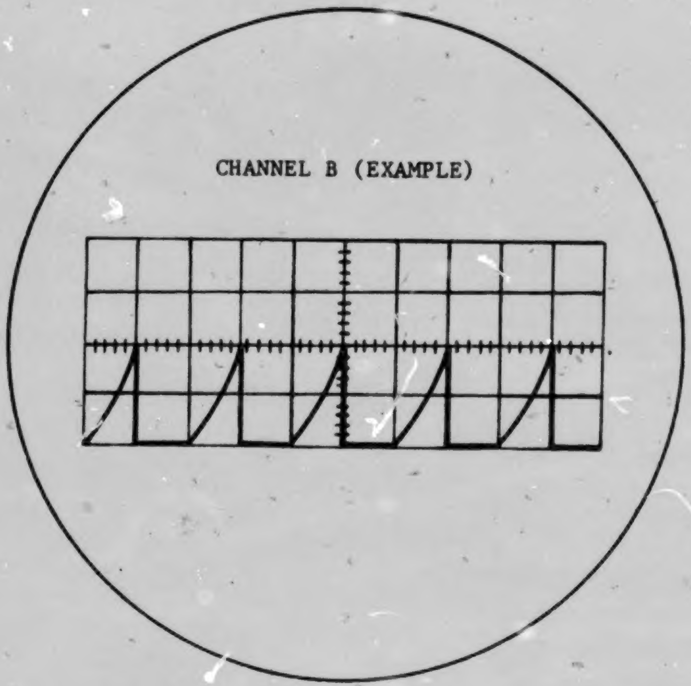
1. POWER Switch off
2. INTENSITY CCW (off)
3. Plug into Outlet
4. POWER Switch ON
5. Select Channel (A or B ONLY)
6. Select TIME BASE A
7. TRIGGERING MODE AUTO
8. TRIGGERING SLOPE + or - INT.
9. HORIZONTAL DISPLAY to 10X EXT.
10. Adjust HORIZONTAL POSITION
11. Adjust VERTICAL POSITION
12. INTENSITY up (CW)
13. ASTIGMATISM (round spot)
14. FOCUS (small spot)
15. HORIZONTAL DISPLAY to A
16. Center Sweep Line
17. Adjust INTENSITY



A ONLY CAL. OUT	4.34 Set the AMPLITUDE CALIBRATOR to 10 volts. To obtain a 2-CM display of a 10-volt signal at the probe tip, you would set the VOLTS/CM control at __________ and the VARIABLE VOLTS/CM in the __________ position.
.5 CALIBRATED	4.35 Use TIME BASE A and set the TIME/CM control at __________ millisec. Now set the rest of the TIME BASE A controls and proceed to compensate your CHANNEL A probe (by unlocking it and turning the front part).
.5	4.36 After the CHANNEL A probe is compensated, do the same with the CHANNEL B probe. Move the __________ switch to B ONLY.
MODE	4.37 When you have finished calibration, place each probe in oscilloscope ground jacks. Next, adjust the VERTICAL POSITION control on each channel, in turn, until the CHANNEL A trace is in the upper half of the grid and the CHANNEL B trace is in the lower half of the CRT, as shown in the figure. Then remove probes from the ground jacks. You are now ready to display a waveform.



CHANNEL A (EXAMPLE)



CHANNEL B (EXAMPLE)

	4.38 Ground the oscilloscope to the Signal Generator, placing the grounding line in the jack marked G on the Signal Generator and in one of the grounding points on the oscilloscope. With the MODE switch at A ONLY, the AC-DC switch at DC, and the Signal Generator Function Switch set at 5, display about 2 cycles of the signal present at Jack A of the Generator. If the signal is negative-going with respect to reference level, use the ______ switch to invert it.
POLARITY	4.39 When you have obtained a good, stable display, use the VOLTS/CM control on CHANNEL A to adjust the display until it is as nearly 2 squares high as possible. When your display is thus set at 2 CM height, use the VERTICAL POSITION control to place the display so that the bottom of the trace rests on the center horizontal grid line. See the upper figure at the left. The display should now fit within the upper half of the grid. If it does not, make necessary adjustments using the VERTICAL ____ and _____/_____ controls.
POSITION VOLTS/CM	4.40 Leave CHANNEL A as it is, with the display in the upper half of the grid and the probe attached to Jack A. Turn the MODE switch to B ONLY. Attach the second probe to CHANNEL B and obtain a display on this channel from the Signal Generator Jack B in the same manner in which you obtained the display for CHANNEL A. Make sure that the waveform has a 'positive-going' appearance, as you did for the CHANNEL A display.
	4.41 When you have a good display, reduce its size to about 2 CM, using the VOLTS/CM control on CHANNEL B, and position this second trace in the lower half of the grid. The bottom of the trace should rest on the bottom line of the grid and the display should fit neatly in the lower half of the grid. See the lower figure.

4.42

Examine the settings of the MODE switch on the Plug-In Unit. The possible settings of the MODE switch are B ONLY, A ONLY, ______, ______, and ______ ______.

ALTERNATE

CHOPPED

ADDED ALGEBRAICALLY

4.43 Whenever you place the MODE switch in the CHOPPED position, the sweep will very rapidly switch between channels during its horizontal movement. This position is desirable for phase comparisons and for dual-trace display of lower frequencies. Place the MODE switch in the CHOPPED position. Do not be alarmed if you lose your display. Go to the next frame.

4.44 Now that you have turned to the CHOPPED position, you may have any of the following conditions on your CRT:

a) You may have two traces stabilized and placed in the upper and lower portions of the grid, respectively. This is the desired condition.
b) You may have no trace at all. If so, try adjusting the INTENSITY control.
c) You may have unstable, jittery displays. If this is so, you will need to select a TRIGGERING MODE other than AUTO and restabilize the display.

4.45

If your display is stable on the upper and lower half of the grid, good. However, for the sake of practice you are to follow the procedures in the next two frames. You may not always be so lucky. When you have a jittery display, the procedures that follow should help you out. Follow the procedures carefully.

4.46

One method is to use the PRESET position of the STABILITY control.

- a) Put the STABILITY control in PRESET (full counter-clockwise to the detent).
- b) Set the TRIGGERING MODE switch to AC.
- c) Rotate the TRIGGERING LEVEL control to obtain a stable display.

4.47 The other method is to start with both the TRIGGERING LEVEL and STABILITY controls fully clockwise.

- a) Set the TRIGGERING MODE switch to AC.
- b) Rotate the STABILITY control counter-clockwise until the trace disappears.
- c) Turn the TRIGGERING LEVEL control counter-clockwise until you have a stable display.

Be sure you have done both of the procedures before going on.

4.48

Use the method in Frame 4.50 to obtain the display for the rest of this section.

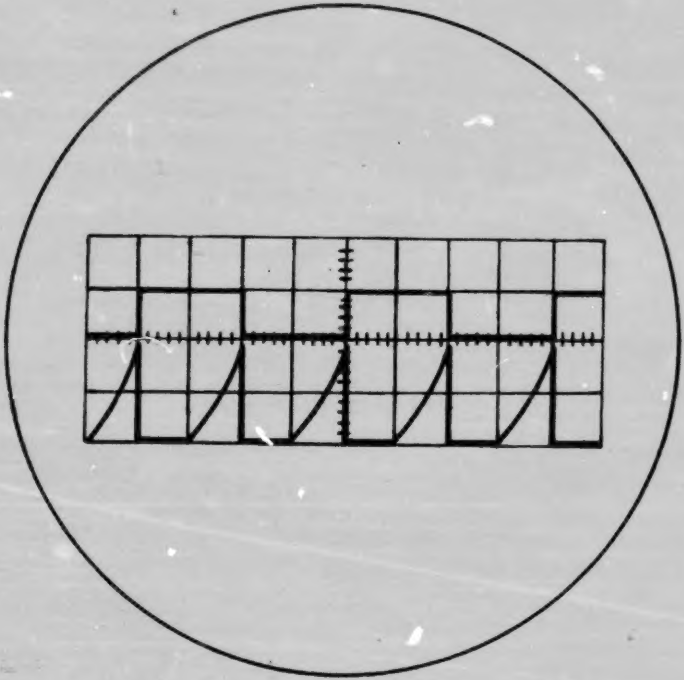
Now turn the TIME/CM control of TIME BASE A to a setting which will give you one or two cycles of the signals. Notice that this control affects both traces.

4.49

If you lose the trace when moving the TIME/CM control, re-establish the display using the method given above in Frame 4.50.

	4.50 You are now ready to measure the amplitudes and voltages of the two displays. Remember, when making voltage measurements you must set the ________ VOLT/CM control in the ________ position. Make sure both channels are set this way.
VARIABLE CALIBRATED	**4.51** Now: a) Count the CM height of the CHANNEL A display and convert this to voltage. Record your result. b) Remember: VOLTS/CM x Probe Atten. x CM Height. c) Measure the voltage of the CHANNEL B display in the same manner and record your finding. d) CHANNEL ________ is receiving the greater voltage.
CHANNEL A 5 volts CHANNEL B 150 volts to 160 volts B	**4.52** You have now made two voltage measurements, in much the same manner as you have done before. There are other, easier ways to make a quick comparison of voltage values. As you follow the instructions in the next few frames, you may lose your display. Be prepared. You know what to do: you s__________ the display. Now continue.
stabilize	**4.53** Using the CHANNEL A VERTICAL POSITION control, move the CHANNEL A display downward and place it on top of the CHANNEL B display. Place it so that the bottoms of the two displays are together. Although the two displays appear to be nearly the same in amplitude, you can make an accurate voltage comparison only when both VOLTS/CM controls have the same setting.

	4.54 Two superimposed displays (one placed on top of the other) can be compared in amplitude only when the two (CHANNEL A & B) _____/_____ controls are set to the same value. This is a good way of comparing voltages that are nearly the same. The voltages at Jack A and B of the Signal Generator are too far apart for comparison by this method. However, we will give you practice in superimposing traces while maintaining stability.
VOLTS/CM	4.55 Leave the VOLTS/CM controls where they are. Now, remembering that you may need to make frequent adjustments on the STABILITY AND TRIGGERING LEVEL controls to maintain trace and display stability, superimpose the two traces in the upper half of the grid. When you finish, return both displays to their halves of the grid and remove your probes from the Signal Generator. Leave the Signal Generator Function Switch set at 5.
	4.56 You are going to make frequency comparisons on the two signals which you just had displayed. This time use TIME BASE B. Set the B TIME/CM control to .5 millisec. and the red ________ control to 10 cm. Turn the HORIZONTAL DISPLAY control to B.
LENGTH	4.57 Display the signal from Signal Generator Jack A through CHANNEL A and the signal from Signal Generator Jack B through CHANNEL B. Do this now. Place your displays as before: A above and B below.



4.58

Turn the TIME BASE B TRIGGERING MODE to the AC position and set the TRIGGER SLOPE at INT+. You will remember that you made identical settings on TIME BASE A when you displayed these two traces using that time base. Again, since you are not using the AUTO position of the TRIGGERING MODE, you may constantly need to stabilize your displays as you proceed. If you need help in remembering the procedure, use the method in Frame 4.47.

4.59

Use the TIME/CM control on TIME BASE B to obtain a minimum of two cycles in each display. One display will have more. Use the figure on the left as an example. Adjust your displays until your presentation resembles this figure.

4.60

A visual comparison of the frequencies of the two waveforms may quickly be made by superimposing the two displays. Do this now.

4.61

Look at the upgoing portions of the two displays. Do any of the upgoing portions occur at the same time? ________. When corresponding points of two waves occur together more than once, it is possible to get an idea of the ratio of the two frequencies. From visual indications, which channel has the higher frequency? ________.

Yes

B

4.62

Return the displays to their sections of the grid. Now compute the frequencies of the displays and record your findings. Remember the VARIABLE TIME/CM control of TIME BASE A must be in the __________ position. TIME BASE B is always calibrated.

$$\text{FREQUENCY} = \frac{1}{\text{CM (1 cycle)} \times \text{TIME/CM (in seconds)}}$$

CALIBRATED

A 250 cps

B 500 cps

4.63

Remove your probes from the Signal Generator.

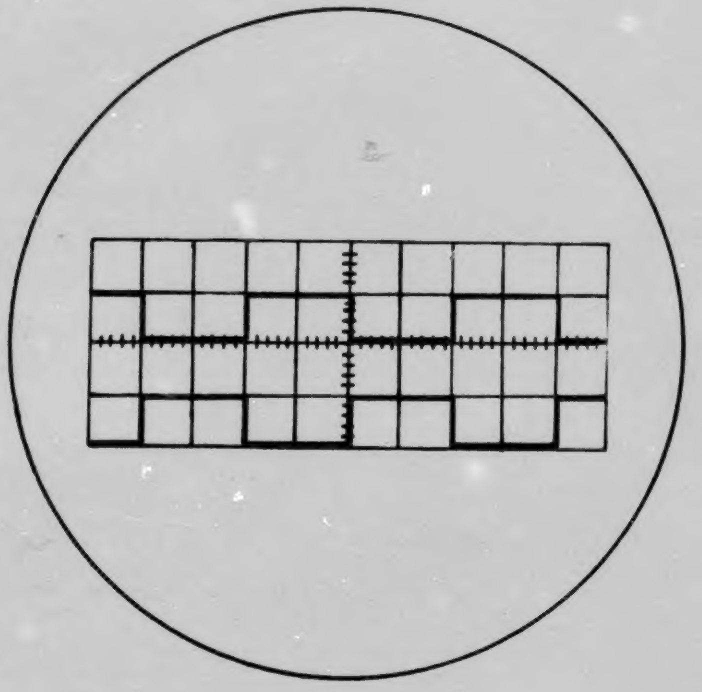
In the next few frames you will be asked to make further comparisons of two signals. You will compare the amplitude, frequency, and phase relationship of square waves. Turn the Signal Generator Function Switch to Position 9. Now set both POLARITY switches at NORMAL.

4.64

Display the Jack A signal in the upper half of the grid. Display the Jack B signal in the lower half of the grid. When you have positioned and stabilized these two displays using the CHOPPED mode, proceed with the program.

4.65

The CHOPPED mode, which causes the sweep to switch rapidly back and forth between channels as it makes a single transit of the grid, is best used when measuring low ________ and when making __________ comparisons.



frequencies phase	4.66 Using the TIME/CM control on TIME BASE B, display at least two complete cycles of the waveforms. Refer to the figure on the left for the desired pattern. Observe the two signals. Based on your observation, the signals are (in/out) ______ of phase.
out	4.67 Turn the POLARITY switch on CHANNEL A to INVERTED. Reposition the display in the upper half of the grid if necessary. The waveforms now appear to be _____ ______. Leave the display in this condition so that it will be easier to make the comparison that follows.
in phase	4.68 Use either CHANNEL A or CHANNEL B VERTICAL POSITION control to place one display exactly over the other. The frequencies of the two displays can now be observed to be _____. Compute the frequency and write your findings on the Response Sheet.
equal (the same) 250 cps	4.69 Make the VOLTS/CM settings of the two channels the same. Observe the amplitude or height of the two displays as they are placed over each other. It is true to say that if the VOLTS/CM settings are the same and the amplitude or height of the displays are the same, then the v______ are the same.

voltages	4.70 Return the displays to their previous positions on the grid. Place both POLARITY switches at NORMAL. You are now going to learn another method of comparing the amplitude of two waveforms. In a moment, using oscilloscope controls,you will algebraically add the two displays. This is not at all difficult since the instrument does all the "algebra".
	4.71 Make sure both VOLTS/CM controls are set at the same value. Your displays represent voltages that are 180 degrees out of phase. In other words, when one is positive-going the other is negative-going. When one is 5 volts positive and the other is 5 volts negative, the algebraic sum (+5 and -5) is zero. On the oscilloscope a zero voltage would appear as a ______ line. This will be true only when equal voltages are 180 degrees out of phase.
straight	4.72 Turn the MODE switch to the ADDED ALGEBRAICALLY position. Observe the vertical position lamps. Adjust either VERTICAL POSITION control to extinguish the vertical position lamps and restabilize. Observe your display. The display represents the added sum of the two out-of-phase voltages. Are the two voltages equal in amplitude? ______(yes/no).
Yes	4.73 The two voltages should be equal in amplitude; however, there may be a slight difference in amplitude from your Signal Generator. If this is true, your trace will not be a straight line. Return the MODE switch to the CHOPPED position and remove your probes from the jacks. THIS COMPLETES SECTION IV, DUAL TRACE OPERATIONS. PROCEED TO SECTION V.

PART E

MAGNIFICATION

AND

HIGH-ACCURACY

TIME-BASE MEASUREMENTS

5.1

PREFACE

PART V

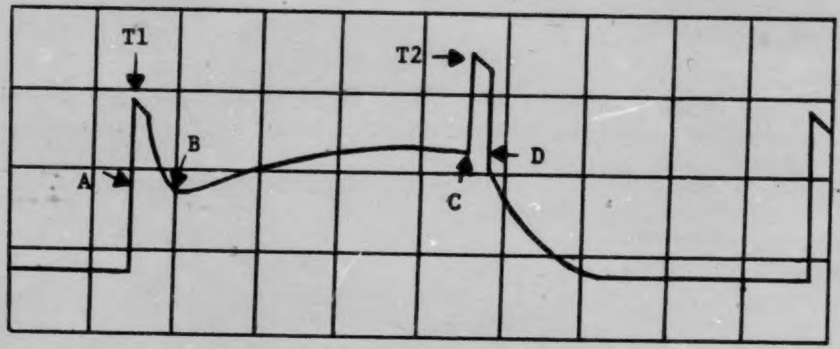
The waveshapes generated within complex electronic equipment often serve as synchronizing pulses, drive pulses, and other such controlling signals which must conform to specific standards. The efficient operation of such equipment is often dependent on seemingly minor characteristics of some of these signals. For this reason visual examination of these signals, using the 545A or similar instruments, is usually a necessary part of any preventive and corrective maintenance procedure where complex systems are concerned.

The maintenance technician, in order to utilize effectively such test instruments as the 545A, must have a clear understanding of the desired characteristics of any waveshape or signal being examined. For this reason the technician will often make use of a "standard" of some type. Sometimes this standard is in the form of a detailed picture of the waveform. At other times the standard is a written description of the critical characteristics of the signal. Often the maintenance technician will have to look up diagrams, technical orders, or other documents to find some standard or set of standards for the signals he wishes to check. This is part of the first step in oscilloscope use: DEFINE YOUR PROBLEM.

Whenever a quick comparison will not give the needed information, the techniques of wave magnification and high-accuracy time-base measurement which you are about to learn become very valuable.

The statements A and B below are based on the PREFACE you have just read. Check the appropriate block on the Response Sheet to indicate your choice of the correct statement(s).

A	B
While the 545A is equipped to make high-accuracy time-base measurements, the average maintenance technician working on complex systems seldom needs to make such measurements. The ability of the 545A to make such measurements is probably built in because the instrument is also used in scientific laboratories.	A "standard" can be either a written statement or a picture.



TIME PERIOD T1 TO T2: 2 MILLISEC.

TIME PERIOD POINT A TO POINT B: .1 MILLISEC.

TIME PERIOD POINT C TO POINT D: .08 MILLISEC.

AMPLITUDE FROM ZERO REFERENCE: -6 VOLTS

B	5.2 Look at the figure on the left. This is a standard. Examine the standard. The amplitude from zero reference is ____ volts in the ____ direction. The duration or length of time from T1 to T2 is _____ millisec. Your problem is to determine if the waveshape at Jack A of the Signal Generator conforms to this standard. You have equipment to assemble and certain controls to preset before you obtain a display.
6 negative 2	5.3 You will need only one probe for this measurement. Remove one of the two probes you have attached to the oscilloscope.
	5.4 Since your instrument has been turned on and checked out, you can proceed to preset some of the controls according to your problem. First use the MODE switch to select the channel that has a probe attached.
	5.5 You will calibrate your instrument again. According to the standard, you will be measuring 6 volts. Set the AMPLITUDE CALIBRATOR to the setting nearest 6 volts.

5.6

Preset your equipment using TIME BASE B and calibrate your instrument for voltage measurement.

5.7

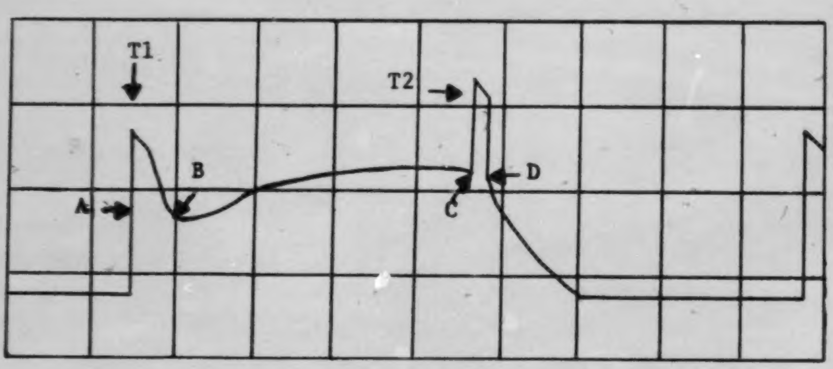
Your problem will include time-base measurement. The output of the AMPLITUDE CALIBRATOR is approximately 1000 cps. Adjust the TIME/CM control until you have at least one complete cycle on display. If you obtain close to 1000 cps, there is no serious malfunction in the sweep circuits or calibration section.

5.8

Turn the Function Switch of the Signal Generator to Position 8. Display the waveshape found at Jack A of the Signal Generator. You may wish to use AUTO position to obtain the display; then switch the TRIGGERING MODE to AC and stabilize the display.

5.9

Remove your probe from Jack A and ground it to establish a zero reference. Now measure the voltage from zero, or reference, to peak negative. You may reverse the POLARITY switch if you wish. Record your finding on the Response Sheet.



TIME PERIOD T1 TO T2: 2 MILLISEC.

TIME PERIOD POINT A TO POINT B: .1 MILLISEC.

TIME PERIOD POINT C TO POINT D: .08 MILLISEC.

AMPLITUDE FROM ZERO REFERENCE: -6 VOLTS

5.3 to 6.6 volts is acceptable

5.10

Use the TIME/CM on TIME BASE B and the HORIZONTAL POSITION control to place at least one complete cycle of the display across the grid. Stabilize if necessary.

5.11 You are already familiar with frequency calculation using the formula:

$$\text{FREQUENCY (cps)} = \frac{1}{\text{No. of CM} \times \text{TIME/CM Setting (seconds)}}$$

You are interested now in calculating time duration, or how long it takes a pulse, a cycle, or some event in the display to occur. You will use only a portion of the formula that you used for frequency. The formula for time is:

$$\text{TIME (sec.)} = \text{No. of CM} \times \text{TIME/CM Setting}$$

5.12

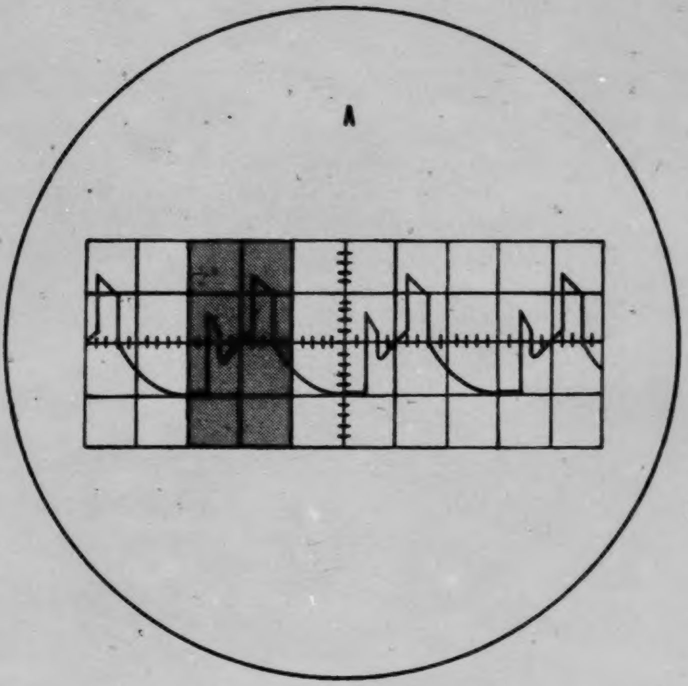
Using the standard (the figure) as a guide, count the number of centimeters on your grid between T1 and T2. Now multiply the number of centimeters by the TIME/CM setting of the time base you are using. (T = No. of CM x TIME/CM setting). Record your finding on the Response Sheet.

2 millisec. (approx.)

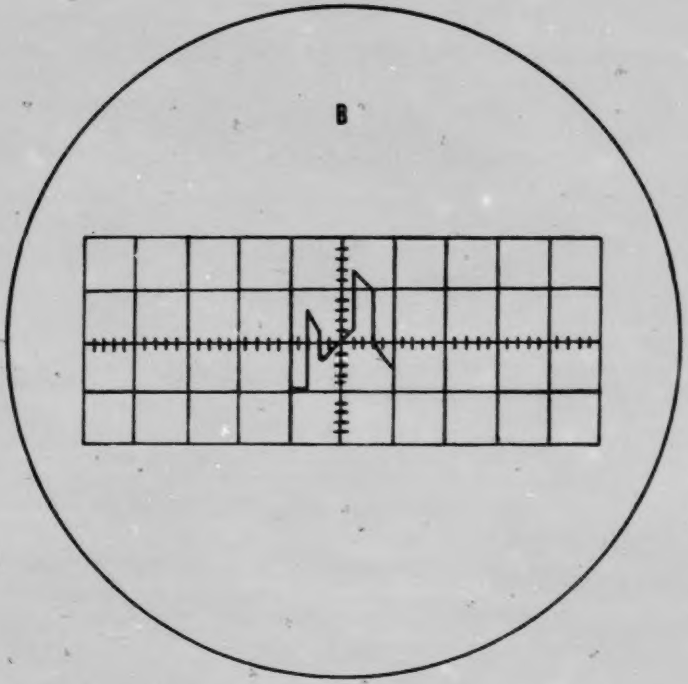
5.13

You will use the same display and measure the time period between T1 and T2 again. This time you will use the 5X MAGNIFIER. The 5X MAGNIFIER will expand a selected portion of your display and allow you greater ease and accuracy in determing length in the waveshape being measured. You will use the 5X MAGNIFIER shortly to ________ a selected portion of the display.

A



B



expand (spread)	**5.14** Using the TIME/CM control, adjust the display until the portion to be measured fits completely within two horizontal CM of the grid; see Figure A. Now, using the HORIZONTAL POSITION control, center the portion to be measured exactly, so that all of it is contained in the middle two CM of the grid; see Figure B.
	5.15 Locate the 5X MAGNIFIER--the red knob on the HORIZONTAL DISPLAY control. Observing the display, turn the 5X MAGNIFIER on. Adjust INTENSITY if necessary. Turn the 5X MAGNIFIER on and off several times, observing the effect of magnification on the center two centimeters of the display.
	5.16 Under magnification you should be able to count more easily the number of centimeters between T1 and T2. The 5X MAGNIFIER will expand the center two centimeters of the display _____ but will not expand the display _____.
horizontally (sideways) vertically (upward)	**5.17** With the 5X MAGNIFIER on, calculate the time between T1 and T2. Your product will have to be divided by 5, as you have multiplied the distance between T1 and T2 by 5. $T = \frac{\text{No. of CM} \times \text{TIME/CM}}{5}$ Record your finding. Turn the 5X MAGNIFIER off.

2 millisec.
(approx.)

5.18 So far you have made a time measurement 2 different ways:

1) Counting the number of _____ between the two points, using a normal display.
2) Counting the number of CM between two points, using a _____ Magnified display.

When computing the time using the second method, you must divide the formula:

TIME = No. of CM x TIME/CM by _________.

CM

5X

5

5.19

You are now going to measure the time period, T1 to T2, using the TIME BASE A and TIME BASE B units of the instrument working together. This is an extremely accurate method of time measurement.

5.20

Use TIME BASE B and obtain on the grid not more than two of the time periods to be measured. Place the TRIGGERING MODE in AC position and stabilize the display through use of the TRIGGERING LEVEL and STABILITY controls.

5.21

Look at the TIME BASE A section of your instrument. In order that this time base can operate along with TIME BASE B, it must be set in what is called a free-running condition. To set TIME BASE A in a free-running condition, turn its TRIGGERING LEVEL and STABILITY controls fully clockwise. Make sure the TRIGGERING MODE of TIME BASE A is in the AC position.

5.22

At this point the display should be controlled and stabilized by TIME BASE B. TIME BASE A should be free running, with the TRIGGERING MODE in the ______ position.

AC

5.23 Soon you are going to use the B INTENSIFIED BY A function of the oscilloscope. When this function is used, the TIME BASE A TIME/CM setting must always be set at some value less than the TIME BASE B TIME/CM setting. For example, if you have the TIME BASE B TIME/CM control set at 50 microsec., the TIME BASE A control must be set at 20 microseconds or less if the B INTENSIFIED BY A function is to be used.

5.24 Now proceed as follows:

a) Set the TIME BASE A TIME/CM control two positions less than, or clockwise from, the TIME BASE B setting of the same control.
b) Make sure the VARIABLE control on TIME BASE A is in the CALIBRATED position.
c) Locate the DELAY-TIME MULTIPLIER above the AMPLITUDE CALIBRATOR and set the number in the window at 2.
d) Turn HORIZONTAL DISPLAY control to B INTENSIFIED BY A.

5.25

Observing your display, adjust the INTENSITY control until you see a dim waveshape with part of it brightened. The brighter portion is the part intensified by the TIME BASE A sweep.

5.26

Before making your measurement, you are to learn more about the operation of the wave-intensification mode.

5.27

Turn the TIME/CM on TIME BASE A clockwise. Notice the intensified portion becomes smaller. Set the TIME/CM on TIME BASE A until the intensification is about one CM in width. Turning the TIME/CM on TIME BASE A clockwise causes the length of the intensified portion to become _____.

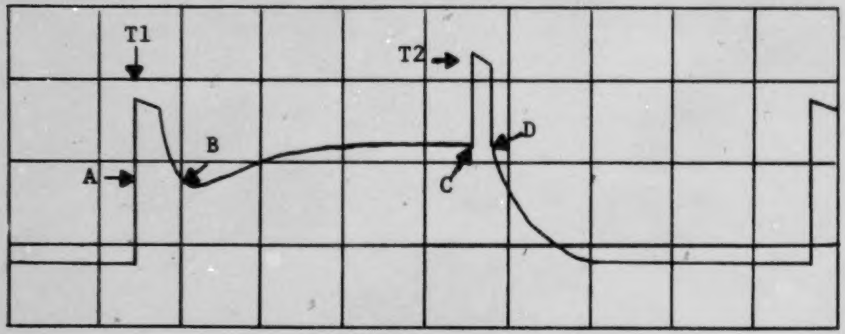
smaller (shorter)

5.28

With the intensified portion set at about 1 CM in length, turn the DELAY-TIME MULTIPLIER. Observe the movement of the intensification. Move the intensification through the length of the display. Now use the TIME/CM control on TIME BASE A to make the intensified portion a very small dot.

5.29

Set the DELAY-TIME MULTIPLIER at zero. Now turn this control slowly clockwise. Notice that the dot moves one centimeter as the DELAY-TIME MULTIPLIER moves from 0 to 1 Set the DELAY-TIME MULTIPLIER at 5. The intensified dot is now positioned on the _____ vertical grid line.



TIME PERIOD T1 TO T2: 2 MILLISEC.

TIME PERIOD POINT A TO POINT B: .1 MILLISEC.

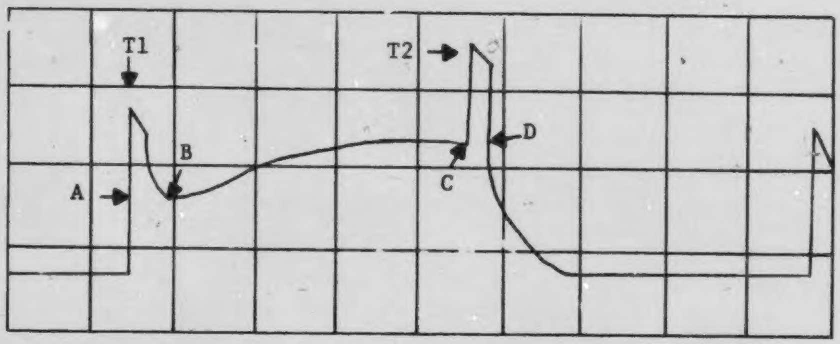
TIME PERIOD POINT C TO POINT D: .08 MILLISEC.

AMPLITUDE FROM ZERO REFERENCE: -6 VOLTS

5th (center)	5.30 Now set the dot back to the extreme left vertical grid line. Move the intensification across the grid and count the vertical lines as you go. Count the first vertical grid line as zero. Check the number of each grid line with the number showing in the window of the DELAY-TIME MULTIPLIER. The numbers should match.
	5.31 Look at the DELAY-TIME MULTIPLIER again. Notice that the numbers nearest the black knob are marked into 100 divisions. When the black knob is rotated one complete turn, the intensified portion moves ______ CM. One of the small divisions on the black knob would indicate movement of the intensification by 1/100 of a ______.
one (1) centimeter (CM)	5.32 Refer to the figure. You are going to measure the time period from the peak at T1 to the peak at T2 once again. Now check the adjustment of the TIME/CM on TIME BASE A and make sure the intensified portion is still visible but forms a very small dot. Use the DELAY-TIME MULTIPLIER to place the dot at the left hand peak at T1. Write down the setting of the DELAY-TIME MULTIPLIER and write beginning after the reading. (Example: 8.14 beginning.) NOTE: Example is for guidance only and does not necessarily represent your trace.
	5.33 Now carefully turn the DELAY-TIME MULTIPLIER clockwise until the dot is set at the peak at T2. Write down this setting of the DELAY-TIME MULTIPLIER and write ending after it. Example: 8.14 beginning 8.52 ending

B INTENSIFIED BY A HIGH-ACCURACY TIME MEASUREMENT

1. Obtain 2-cycle display, using TIME BASE B.
2. Set TIME BASE A to free run.
3. Set TIME/CM of TIME BASE A less than TIME/CM of TIME BASE B.
4. HORIZONTAL DISPLAY to B INTENSIFIED BY A.
5. Adjust INTENSITY.
6. Adjust TIME/CM of TIME BASE A until intensified portion is a small spot.
7. Use DELAY-TIME MULTIPLIER to set spot on one point of pulse to be measured.
8. Record setting as starting point.
9. USE DELAY-TIME MULTIPLIER to move spot to next point on pulse to be measured.
10. Record new setting of DELAY TIME MULTIPLIER as ending point.
11. Subtract beginning from ending settings.
12. Multiply result by TIME BASE B TIME/CM setting.



TIME PERIOD T1 TO T2: 2 MILLISEC.

TIME PERIOD POINT A TO POINT B: .1 MILLISEC.

TIME PERIOD POINT C TO POINT D: .08 MILLISEC.

AMPLITUDE FROM ZERO REFERENCE: -6 VOLTS

	5.34 Now subtract the beginning from the ending and write your result. Example: 8.52 ending -8.14 beginning .38 result
	5.35 The formula for time is: TIME = TIME/CM Setting x Movement of DELAY-TIME MULTIPLIER Multiply the TIME/CM setting on TIME BASE B by the result. Example: TIME/CM .5ms x .38 result = .19 millisec. NOTE: Example is for guidance only and does not necessarily represent your figures.
2 millisec. (approx.)	5.36 Your result should be about two milliseconds for the time period between T1 and T2. Due to slight variations within the Signal Generator, your reading may have been between 1.85 and 2.15 milliseconds. If you are within that range, you did very well and should go to the next frame. If you obtained a different measurement, refer to the upper figure and recompute the measurement before proceeding.
	5.37 Refer to the lower figure. Notice the width of the T1 pulse between points A and B. You are to measure this pulse width. Be sure the intensified portion is a dot. Measure the time period of this width, using the DELAY-TIME MULTIPLIER as you did previously. Record your finding.

.1 millisec.
(.08-.12
acceptable)

5.38

Remove your probe from the Signal Generator and turn the intensity all the way down. Now let's review for a moment. You have used three types of displays to measure time.

1. The first was a normal display.
2. The second was a _____ _____ display.
3. The third was a ______ _____ by _____ display.

5X Magnified

B Intensified A

5.39

The basic formula for calculating time is: Time equals number of _____ times _____/__ __ setting. When using the 5X Magnified display, this formula must be divided by _____.

CM

TIME/CM

5

5.40

When using the B Intensified by A display, the formula becomes: Time equals: number of divisions the ______ - ______ _____ is moved, times the ______/_____ setting of TIME BASE ________.

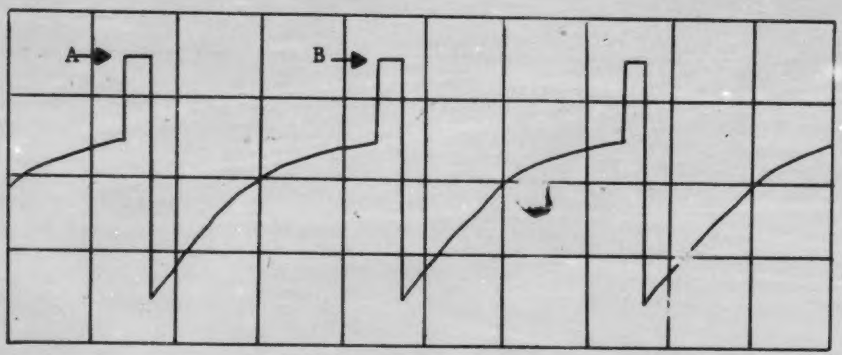
DELAY-TIME
MULTIPLIER

TIME/CM

B

5.41

Now turn the POWER switch on the oscilloscope off. Turn all oscilloscope controls which have more than two positions completely counter-clockwise. Remove the probe from the scope.



1. MEASURE TIME PERIOD OF PULSE WIDTH AT A.

2. MEASURE TIME PERIOD BETWEEN A AND B.

	5.42 Let's start this problem from the beginning. The first step is to __________ Your __________. Look at the figure. This figure represents the signal which you will obtain at Jack B of the Signal Generator when the Function Switch is set at Position 3. The portions of the waveshape to be measured are shown in this figure. Set FS1 of the Signal Generator to Position 3.

Define Problem	5.43 Now you must __________ __________. Next you __________ __________ and __________ __________ the oscilloscope. Don't forget to start with the intensity __________. Now complete the turn-on procedure.

Assemble Equipment Turn On Check Out CCW (down,off)	5.44 Set up a free-running sweep,using the AC triggering mode of TIME BASE A. The STABILITY and TRIGGERING LEVEL controls must be in their extreme __________ positions. To get a dot on the screen, you put the HORIZONTAL DISPLAY control in __________ X10 position.

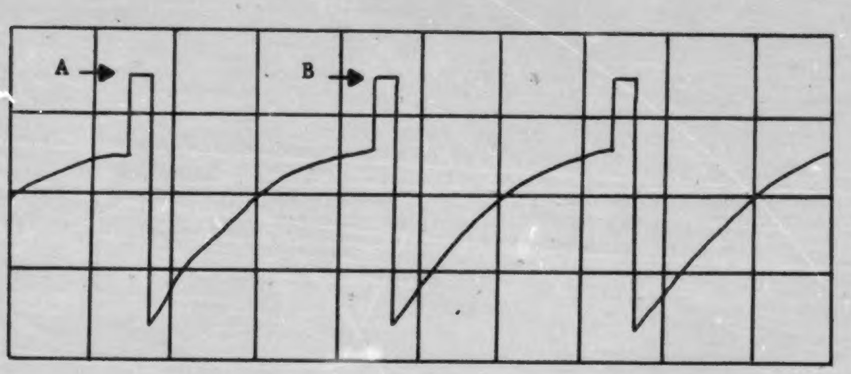
clockwise EXT	5.45 Now obtain a spot which is round, as small as possible, and in the center of the screen. Turn the HORIZONTAL DISPLAY to __________ and obtain a sweep line.

A	5.46 You are now ready to _____ and _____ your oscilloscope. Select an input channel with the _____ switch. Now connect a _____ to the selected channel.

Preset Calibrate MODE probe	5.47 Preset TIME BASE B. Set the TRIGGERING MODE to ______ and the SLOPE to +______. Set the TIME/CM control to _______ milliseconds, or the middle of the range.

AUTO INT .5	5.48 When your controls are in the positions given, move the HORIZONTAL DISPLAY switch to ______. Now set the AMPLITUDE CALIBRATOR to 10 volts and the VOLTS/CM switch on the selected channel to obtain a display 2 CM high.

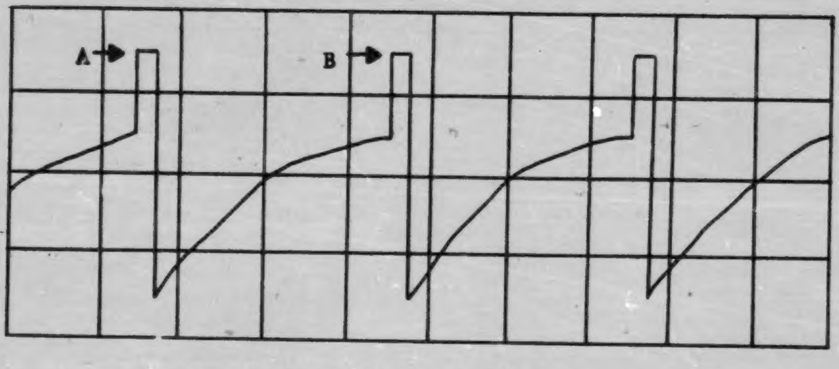
B	5.49 Connect the probe to the CAL. OUT jack and ______ the probe to obtain perfect square waves in your display.



1. MEASURE TIME PERIOD OF PULSE WIDTH AT A.

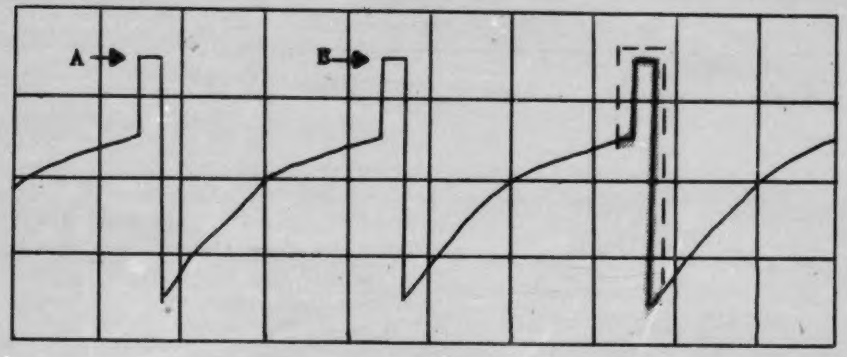
2. MEASURE TIME PERIOD BETWEEN A AND B.

adjust (compensate)	5.50 Since the voltage and frequency of the signal to be measured are both unknown, set the VOLTS/CM control to ______ and leave the TRIGGERING MODE and SLOPE in the ______ and ______ ______ position, respectively.
20 AUTO + INT	5.51 There are two controls yet to be checked and set. Look at the selected channel and make sure the AC-DC switch is in the ______ position and that the _____ switch is in NORMAL.
DC POLARITY	5.52 Now you are ready to _____ and _____ a Display. Connect the probe to Jack B of the Signal Generator. (Make sure you didn't forget a ground connection.) Now obtain a display of the signal at Jack B.
Obtain Evaluate	5.53 Look at the figure. .You are going to make accurate time measurements. One very good method of doing this is to use a display of ______ Intensified by ______.



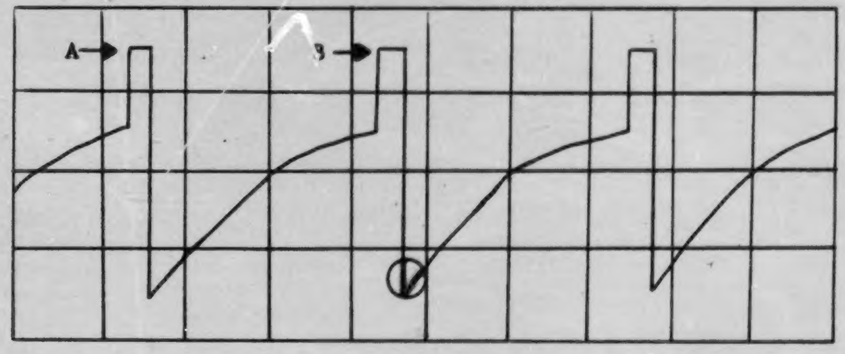
1. MEASURE TIME PERIOD OF PULSE WIDTH AT A.
2. MEASURE TIME PERIOD BETWEEN A AND B.

B A	5.54 Go to the AC triggering mode and stabilize your display, using the _____ and _____ _____ controls. Now adjust the TIME/CM control of TIME BASE ______ so that you have at least 2 repetitions of both time periods to be measured. See the figure.
STABILITY TRIGGERING LEVEL B	5.55 Now adjust the TIME/CM control of TIME BASE ______ so that it is set two positions less than, or ______ from, the TIME/CM control of TIME BASE B. Put the VARIABLE TIME/CM control of TIME BASE A in the _______ position.
A clockwise CALIBRATED	5.56 Now move the HORIZONTAL DISPLAY switch to ______ ______ BY A. Stabilize the display if necessary and reduce the brightened portion of the display to a just-visible ______.
B INTENSIFIED spot (dot)	5.57 Now measure the two time durations indicated as 1 and 2 in the figure. To do this, use the ____ - ______ MULTIPLIER and record your answers on your Response Sheet.



1. MEASURE TIME PERIOD OF PULSE WIDTH AT A.
2. MEASURE TIME PERIOD BETWEEN A AND B.

DELAY-TIME .05 milliseconds (.04 to .06 good) 2 milliseconds (1.9 to 2.1 good)	5.58 Now measure the peak-to-peak voltage of your display and record your finding. Disregard any distortion or "hash" which may be visible on your display.
12 V_{p-p} (11.5 to 12.5 good)	5.59 With the same display, use the TIME BASE A TIME/CM control to lengthen the intensified portion of the waveform. Next use the DELAY-TIME MULTIPLIER to place the intensified portion at the top of the upgoing pulse. Readjust the TIME BASE A TIME/CM control until the whole pulse is intensified. See the figure.
	5.60 Locate the A DELAYED BY B position of the HORIZONTAL DISPLAY control and turn the control to this position. Adjust the INTENSITY control if necessary. The display you now see is just that portion of the signal you previously had intensified.
	5.61 Switch the HORIZONTAL DISPLAY to B INTENSIFIED BY A and then back to A DEL'D BY B, observing the display as you do this. The intensified portion is greatly _______ in the A DEL'D BY B position.



1. MEASURE TIME PERIOD OF PULSE WIDTH AT A.

2. MEASURE TIME PERIOD BETWEEN A AND B.

magnified
(larger)

5.62 The magnification of the A DEL'D BY B position is excellent for viewing short pulses and transients. The amount of magnification is the ratio of the TIME BASE B TIME/CM setting to the TIME BASE A TIME/CM setting when the VARIABLE TIME/CM control of TIME BASE A is in the _____ position. Example:

$$\frac{\text{TIME BASE B TIME/CM} \quad .5\ \text{millisec.} = .0005\ \text{sec.}}{\text{TIME BASE A TIME/CM} \quad 20\ \text{microsec.} = .00002\ \text{sec.}} = 25$$

CALIBRATED

5.63

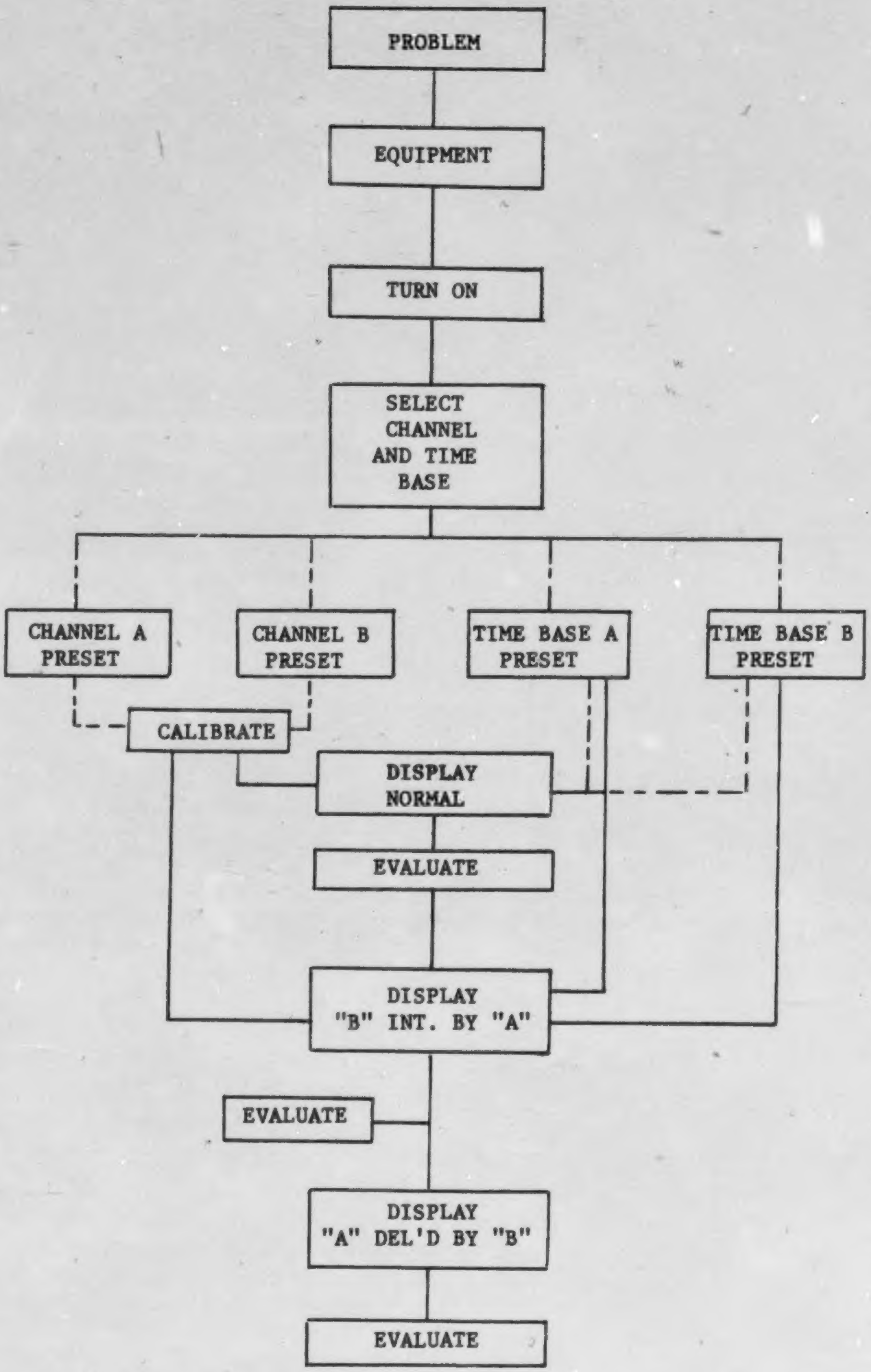
In the example, 25 is the magnification factor, or number of times the portion you have selected by intensification has been enlarged. Just as you learned to divide all calculations by 5 when you use the 5X MAGNIFIER, you would divide in this case by 25. To calculate a time, then, you count CM, multiply by the TIME BASE B TIME/CM setting, and divide the answer by the magnification factor.

5.64

Place the HORIZONTAL DISPLAY control in the B INTENSIFIED BY A position. Now adjust the length of the intensification with TIME BASE A TIME/CM control and position with the DELAY-TIME MULTIPLIER until just the bottom tip of the downgoing portion is intensified. See the figure.

5.65

Turn the HORIZONTAL DISPLAY control to A DEL'D BY B. Examine your display and notice how it is magnified. You may have to increase the INTENSITY considerably to see the magnified display well. Divide the TIME BASE A TIME/CM into TIME BASE B TIME/CM setting and write down the magnification factor. Remember when you return the HORIZONTAL DISPLAY to other modes you must reduce INTENSITY.


PROBLEM
EQUIPMENT
TURN ON
SELECT CHANNEL AND TIME BASE
CHANNEL A PRESET
CHANNEL B PRESET
TIME BASE A PRESET
TIME BASE B PRESET
CALIBRATE
DISPLAY NORMAL
EVALUATE
DISPLAY "B" INT. BY "A"
EVALUATE
DISPLAY "A" DEL'D BY "B"
EVALUATE

Value depends on your control settings.

5.66

Remove your probe from the jack and turn the HORIZONTAL DISPLAY control to A or to B. Reduce INTENSITY.

5.67

Look at the figure. This figure is a diagram which will help you review the steps necessary to arrive at the various display conditions you have practiced. The dotted lines mean that you could choose either or both path(s) to the next step. Examine the figure closely now.

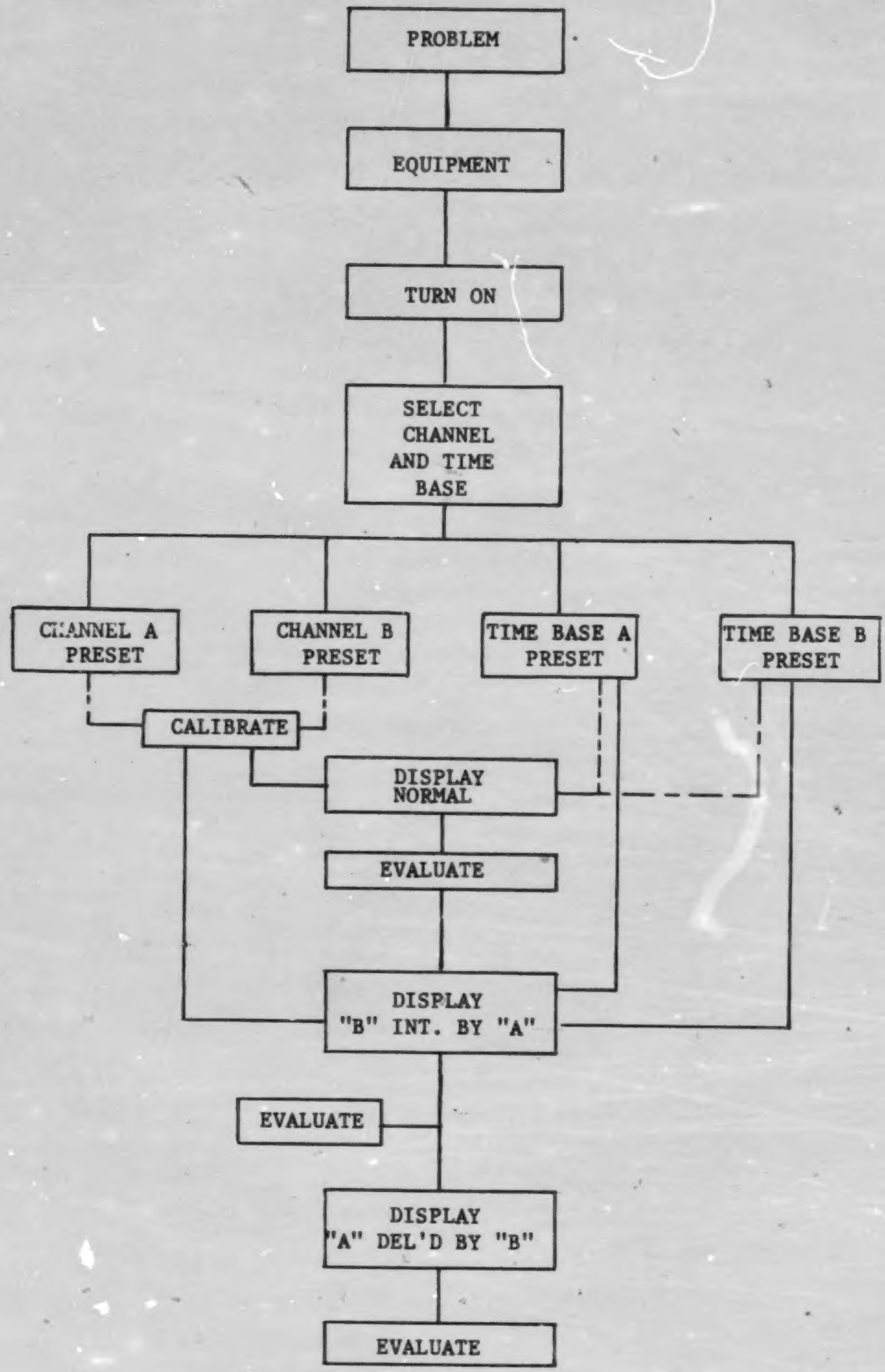
5.68

When you use the oscilloscope, or nearly any test instrument, your first step is to D_____ _____ _____. The display you finally obtain will have a vertical component, or part, contributed through either CHANNEL A or CHANNEL B. It will also have a horizontal component contributed through TIME BASE A, TIME BASE B, or both of the time bases simultaneously.

Define Your Problem

5.69

Referring to the figure, notice that before you arrive at the A DEL'D BY B display you are first required to obtain a display in the _____ _____ _____ _____ mode. Display in the B INTENSIFIED BY A mode would require the use of both TIME BASE A and TIME BASE B.


PROBLEM
EQUIPMENT
TURN ON
SELECT CHANNEL AND TIME BASE
CHANNEL A PRESET
CHANNEL B PRESET
TIME BASE A PRESET
TIME BASE B PRESET
CALIBRATE
DISPLAY NORMAL
EVALUATE
DISPLAY "B" INT. BY "A"
EVALUATE
DISPLAY "A" DEL'D BY "B"
EVALUATE

B INT. BY A	5.70 When using either B INTENSIFIED BY A or A DEL'D BY B, the VARIABLE TIME/CM control of TIME BASE A must be in the __________ position. The next few frames contain imaginary measurement problems about which you are to answer questions by referring to the figure. Read the problems, answer the questions, and write your answers on the Response Sheet.
CALIBRATED	5.71 If your "problem" is: 'Measure the voltage at test point "X",' list on your Response Sheet the channel(s) and the time base(s) you would use to obtain and evaluate a display for this problem.
CHANNEL A or B TIME BASE A or B	5.72 If your problem is: 'Compare two displays to determine if the amplitudes and frequencies are equal', list the channel(s) and time base(s) necessary to do this.
CHANNEL A and B TIME BASE A or B	5.73 If your problem is: 'Magnify the upgoing pulse at Jack "X" 50 times and determine if it is distorted', list the channel(s) and time base(s) necessary to do this.

CHANNEL A or B TIME BASE A and B	5.74 You have now completed the measurement problems of Section V. You learned four things: two methods of wave magnification and two methods of high-accuracy time-base measurement. One way to magnify a waveform is to place it in the _____ position of the grid and then turn the _____ ______ on.
center 5X MAGNIFIER	5.75 A second method of magnification is to intensify a portion of a waveform using the ______ _____ _____ ______ position of the _____ DISPLAY control and then switch to the _____ ______ _____ _____ position of the ______ DISPLAY control.
B INTENSIFIED BY A HORIZONTAL A DEL'D BY B HORIZONTAL	5.76 One very accurate method of time-base measurement is to reduce the _____ portion of a waveform to a small______ and move this ______ along the length to be measured, using the D______ -T________ M________ control. To do this, the HORIZONTAL DISPLAY control must be in the ______ ______ ______ ______ position.
intensified dot (spot) dot (spot) DELAY-TIME MULTIPLIER B INTENSIFIED BY A	5.77 THIS ENDS SECTION V, MAGNIFICATION AND HIGH-ACCURACY TIME-BASE MEASUREMENT. THE NEXT SECTION INCLUDES SOME INTERESTING AND USEFUL FACTS ABOUT THE 545A. YOU ARE READY TO PROCEED WITH SECTION VI, "A LITTLE MORE ABOUT THE 545A."

PART F

A LITTLE MORE ABOUT THE MODEL 545A

6.1

Throughout the program you have used either the P6000 or P6006 probe. As you have already learned, this type probe has an attenuation factor of ten. It will be capable of handling most of your problems. Should you be required to use probes other than the ones with which you have become familiar, it is well to determine the attenuation factor, if any, to insure that you accurately compute the voltage. A word of caution -- the use of unattenuated probes in troubleshooting transistorized circuits may cause a "loading" condition which will damage the transistors.

Read the following and indicate the correctness of these statements on your response sheet. Check the correctness of your answer at the bottom of each page in this section of the program.

A	B
Always use attenuated probes in checking transistorized circuits.	The P6006 probe has an attenuation factor of 10.

6.2

Locate the AC-DC switches on the Plug-In Unit. You will recall that you have made your measurements with these switches set at DC. The AC position has a capacitor input to the scope, while the DC is directly coupled. In most instances the DC position is satisfactory; even for an ac input. The AC position is used primarily to remove a dc component from an alternating voltage.

Indicate the correctness of these statements:

A	B
The DC position may be used with both ac and dc inputs.	Use of the DC position will remove the dc component from an ac input.

CONFIRMATION:
6.1 : Both
6.2 : A

6.3

You have learned that the VARIABLE on the VOLTS/CM control cluster should be in the "click" or CALIBRATED position. This is essential during voltage measurements. When you are not concerned with voltage measurement, you may wish to increase or decrease the amplitude to levels between the settings of the VOLTS/CM. The VARIABLE will allow you to do this.

Indicate the correctness of these statements:

A	B
The VARIABLE on the VOLTS/CM must be in the CALIBRATED position during accurate voltage measurements.	The position of the VARIABLE on the VOLTS/CM would have no effect on frequency measurement.

6.4

Notice the ALTERNATE and CHOPPED positions of the MODE switch on the Plug-In Unit. When you select the ALTERNATE position, the sweep moves completely across the CRT on CHANNEL A; then it sweeps across on CHANNEL B. It 'alternates' from channel to channel. At slow sweep speeds, this condition is readily observable. The ALTERNATE position is desirable for displaying frequencies above 10 KC.

In the CHOPPED position, the sweep very rapidly switches from channel to channel as it moves across the CRT. The CHOPPED position is better for the lower frequencies and it is necessary for phase comparisons.

Indicate the correctness of these statements:

A	B
The ALTERNATE position should be used for frequencies below 10 KC.	The CHOPPED position is best suited for phase comparisons.

CONFIRMATION: 6.3 Both 6.4 B

6.5

Consider the TRIGGERING MODE controls on TIME BASES A and B. TIME BASE A has five positions, while TIME BASE B has only three. You are familiar with the AUTO position. It offers more convenience and allows you to obtain a display readily. As you have observed, however, the AUTO position does not always give stability to your display. The AC position will usually serve to stabilize the display when the AUTO position proves unsatisfactory. The balance of the positions on the TRIGGERING MODE control will meet special conditions.

Which of these statements are true?

A	B
Both TIME BASE A and TIME BASE B have "AUTO" positions.	AUTO position will always give a stable display.

6.6

You have used the +INT position of the TRIGGER SLOPE control on TIME BASE A and on TIME BASE B. Here, the trigger to the sweep is taken from the positive-going portion of the input. This means that when you place your probe into a test jack, the first positive-going portion of the signal causes the sweep to start across the CRT. The -INT would give the same effect, except that the sweep would start from the first negative-going portion of the signal from the input. The LINE position provides a trigger to the sweep from the ac power input to the scope. In most cases this is 60 cps. Synchronization of the input to the Plug-In Unit and the sweep cannot be obtained unless the input is 60 cycles or some multiple of 60. The EXT position is for use when an external source is used to trigger the sweep.

Indicate the correctness of these statements:

A	B
With the TRIGGER SLOPE control set at -Line, a 50 cycle input to CHANNEL A would appear very stable on the CRT.	The INT position triggers the sweep from the input to the Plug-In Unit.

CONFIRMATION: 6.5 A 6.6 B

6.7

You have used most of the positions of the HORIZONTAL DISPLAY control. Notice the "A" SINGLE SWEEP position. Often when you display a signal which is varying in amplitude and time, such as a randomly triggered oscillator, the normal repetitive sweep on the CRT causes a "hazy" and poorly defined display. The "A" SINGLE SWEEP feature will display one sweep which will give a brief but sharply defined view of the waveshape. The RESET button is usually used to start the single sweep.

The EXT position of the HORIZONTAL DISPLAY may be used to deflect a display horizontally with an external signal. A graph comparison or "plotting" of two voltages can be accomplished through use of this control position.

Indicate the correctness of these statements:

A	B
The HORIZONTAL DISPLAY CONTROL selects the vertical channel on the Plug-In Unit.	Selection of TIME BASE B may be made through use of the HORIZONTAL DISPLAY control.

6.8

You are quite familiar with the AMPLITUDE CALIBRATOR and its output jack. Other output jacks include the VERT. SIG. OUT, SAWTOOTH A, +GATE A, +GATE B, and DEL'D TRIG. These jacks have outputs which may be used to drive or synchronize other equipment. The CAL. OUT has an output which is variable in amplitude only. The output jacks +GATE A, +GATE B, and SAWTOOTH A are variable in frequency only, through manipulation of the TIME/CM controls.

Indicate the correctness of these statements:

A	B
The output of the CAL. OUT jack is variable in frequency and amplitude.	SAWTOOTH A output can be varied in frequency but has a constant amplitude.

CONFIRMATION: 6.7 B 6.8 B

6.9

At the top rear of the oscilloscope there is a two-position toggle switch and a pair of binding posts. The usual position of the switch is to the CHOPPED BLANKING position when the binding posts (EXTERNAL CRT CATHODE and GROUND) are connected with a removable, metal strap. In the CHOPPED BLANKING position, the transition trace is less visible as the sweep moves from channel to channel in the CHOPPED mode. With the toggle switch in the EXTERNAL CRT position and the strap removed, an external signal may be applied to the binding posts as an intensity-modulation signal. A pulse injection here would cause the display to have a "dotted" appearance and could serve as controlled markers for measurements and comparisons of timing signals.

Which of these statements are true?

A	B
Usually, during such problems as you have performed, the toggle switch should be placed in the EXTERNAL CRT CATHODE position.	For intensity modulation, the metal strap should be removed and an external signal connected to the binding posts.

6.10

You have completed the program on the use of the Model 545A Oscilloscope. You are able to use the oscilloscope to measure voltage and frequencies and are now able to use the special features of the scope to make dual-trace comparisons and very accurate evaluations of intricate waveshapes. You have reached a high degree of skill. Your skill, however, will fade without practice. It will be necessary for you to perform measurements with the 545A often during the next few weeks to retain your skill.

CONFIRMATION: 6.9 B

SECTION III

545A RESPONSE BOOKLET

The response booklet is provided for recording your responses or answers to the blanks and questions in the Frames. You should enter the response for a Frame next to the Frame number on the response sheets. After you have completed your response you may confirm its correctness by referring to the left hand or confirmation section of the next Frame. There is sufficient space provided for you to make any necessary mathematical calculations right on the response sheets.

1.2 ______________________________

1.3 ______________________________

1.4 ______________________________

____

1.5 ______________________________

1.6 ______________________________

1.7 ______________________________

____

____

____

1.8 ______________________________

____

1.9 ______________________________

1.10 ______________________________

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1.23 a.____INTENSITY
b.____VOLTS/CM
c.____ASTIGMATISM
d.____SCALE ILLUM.
e.____GAIN ADJUST
f.____AC-DC Switch
g.____FOCUS
h.____STABILITY CONTROL

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4.1 A____ B____ Neither____ Both____

4.2 A____ B____ Neither____ Both____

4.3 A____ B____ Neither____ Both____

4.4 A____ B____ Neither____ Both____

4.5 A____ B____ Neither____ Both____

4.6 A____ B____ Neither____ Both____

4.7 A____ B____ Neither____ Both____

4.8 A____ B____ Neither____ Both____

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5.1 A____ B____ Neither____ Both____

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6.1 A____ B____ Neither____ Both____

6.2 A____ B____ Neither____ Both____

6.3 A____ B____ Neither____ Both____

6.4 A____ B____ Neither____ Both____

6.5 A____ B____ Neither____ Both____

6.6 A____ B____ Neither____ Both____

6.7 A____ B____ Neither____ Both____

6.8 A____ B____ Neither____ Both____

6.9 A____ B____ Neither____ Both____

APPENDIX I

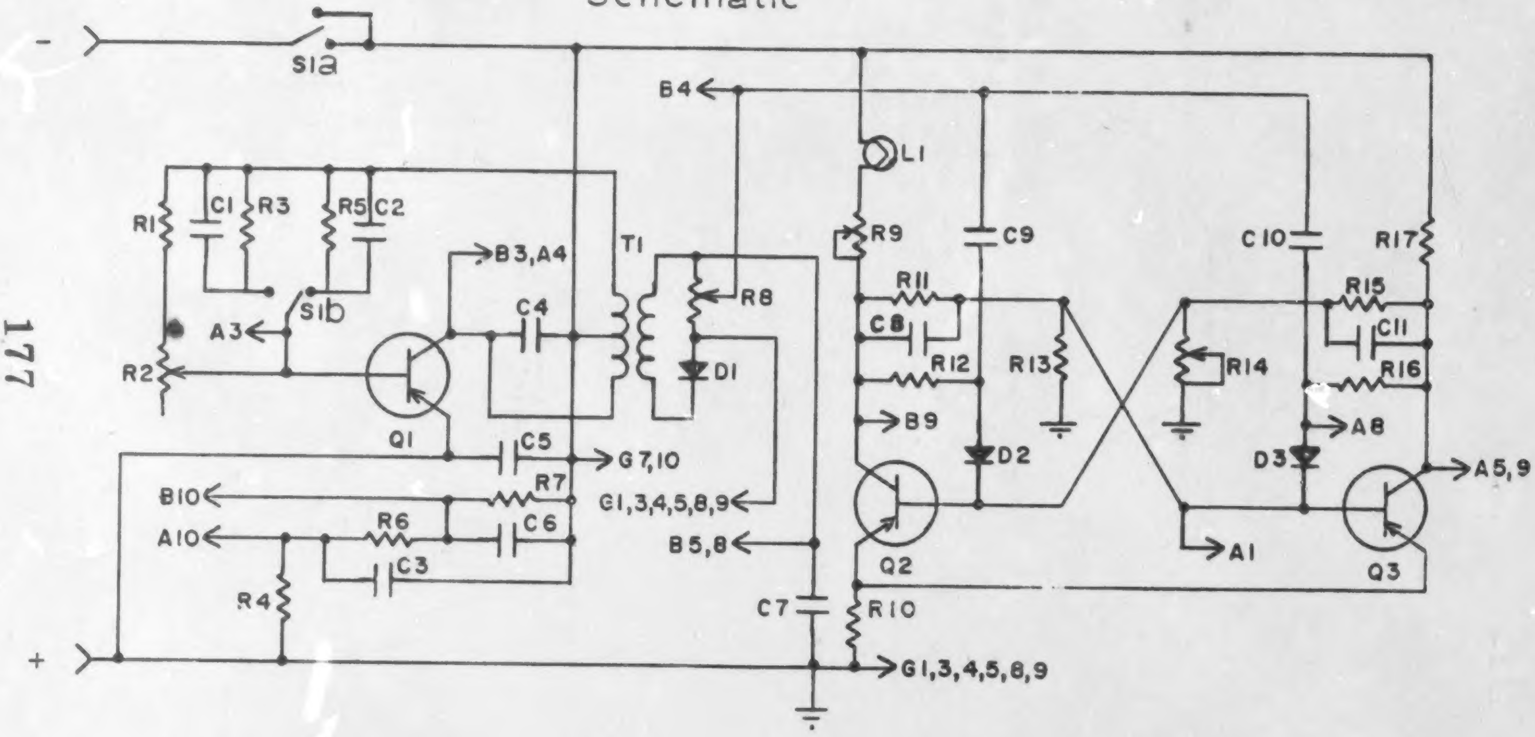
TECHNICAL INFORMATION
ON THE
TSG-1 SIGNAL GENERATOR
FOR USE WITH THE
INSTRUCTIONAL PROGRAM ON OPERATION
OF THE
TEKTRONIX 545A OSCILLOSCOPE

INTRODUCTION

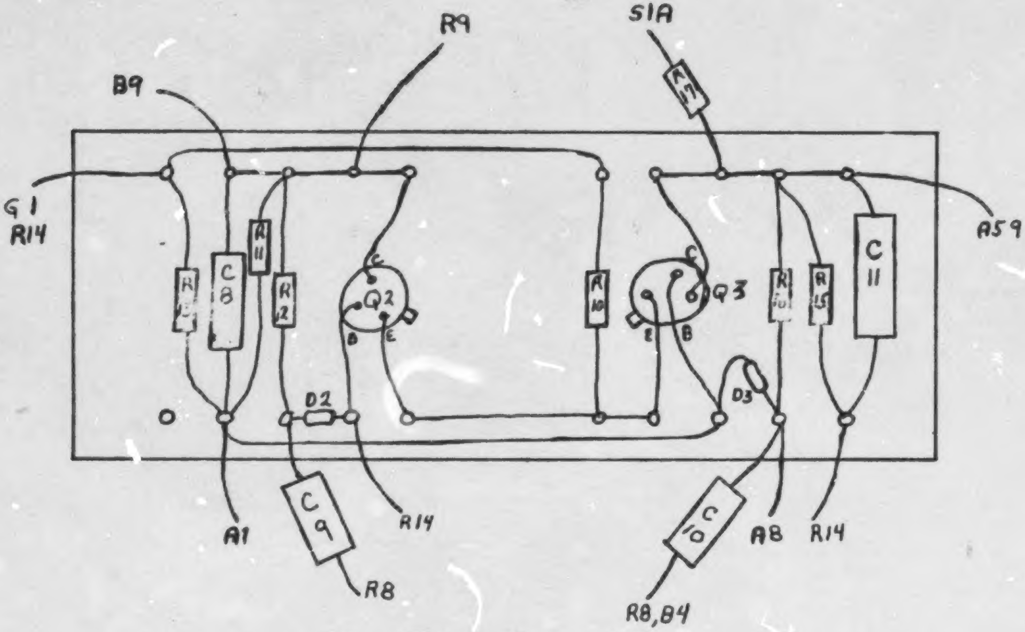
The TSG-1 is a small, special-purpose signal generator. It was designed specifically as an accessory to an instructional program on the Tektronix 545A oscilloscope, and is not intended for any other use.

The following pages give complete instructions for construction and alignment of this device.

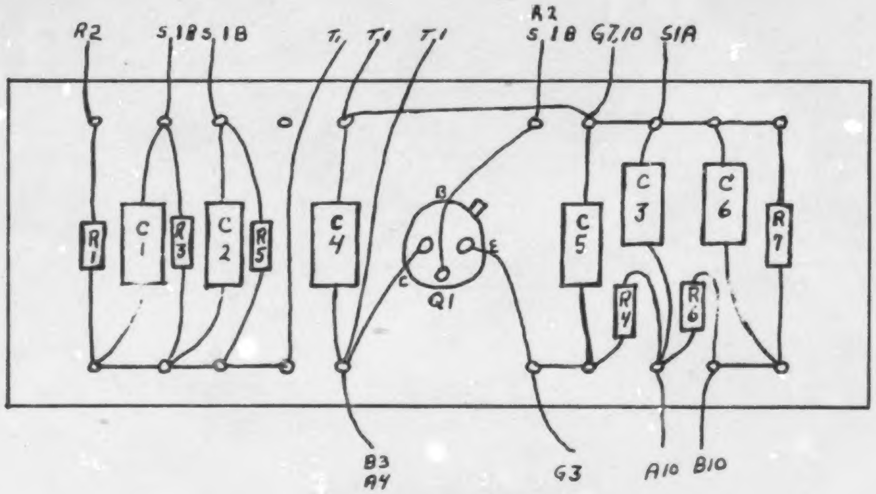
TSG-1
Signal Generator
Schematic


-
+
SIa
SIb
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
D1
D2
D3
L1
T1
Q1
Q2
Q3
A3
B3,A4
G7,10
B10
A10
G1,3,4,5,8,9
B5,8
B4
B9
A8
A1
A5,9
G1,3,4,5,8,9

TSG-1
Parts Layout

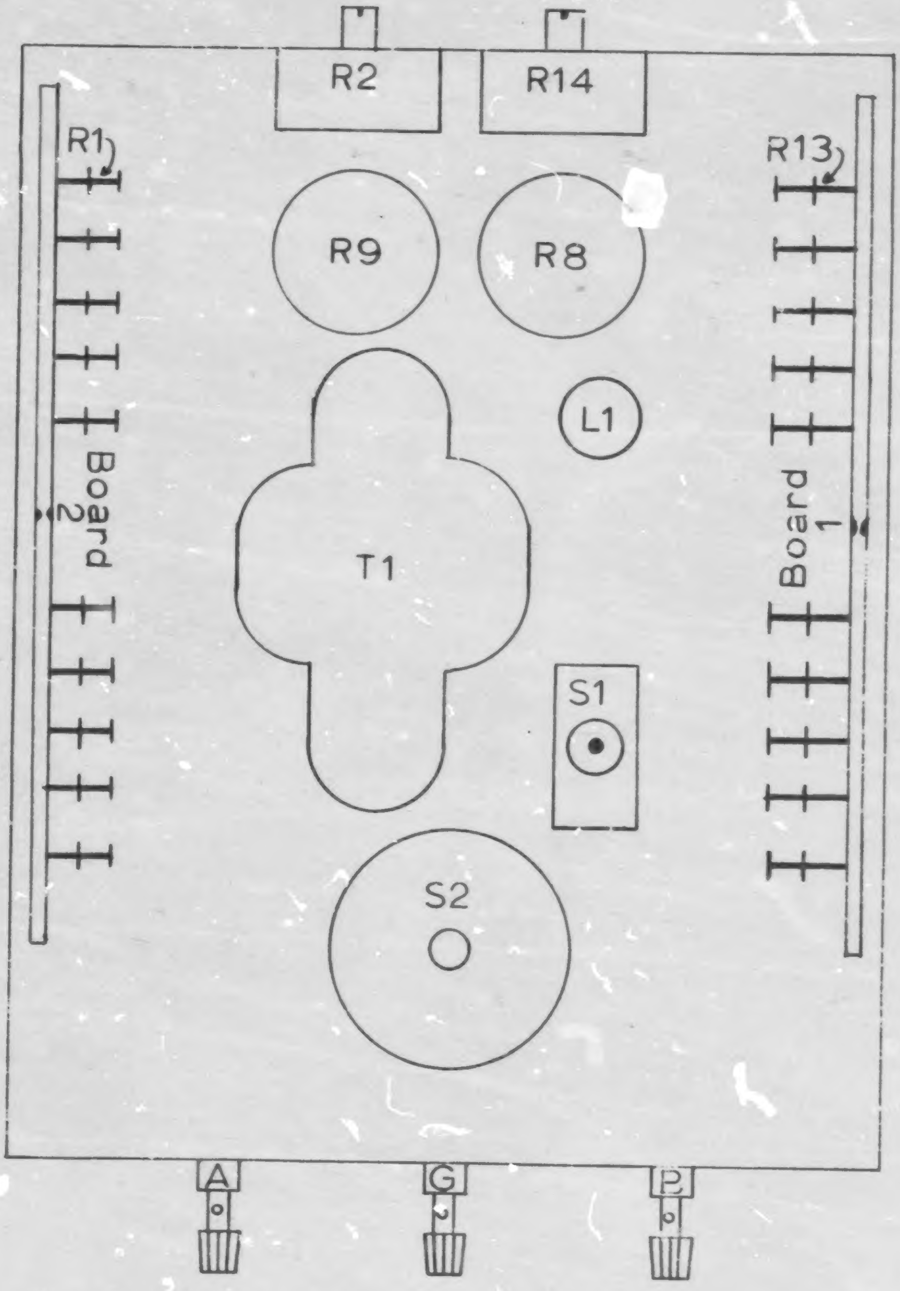

R9
S1A
B9
R17
G1
R14
A59
R13
C8
R11
R12
Q2
C
B
E
R10
Q3
C
E
B
R16
R15
C11
D2
D3
C9
R14
A1
R8
C10
A8
R14
R8, B4

Flip-Flop, Board1


R2
S.1B
S.1B
T1
T1
T1
R2
S.1B
G7,10
S1A
R1
C1
R3
C2
R5
C4
B
E
C
Q1
C5
C3
C6
R7
R4
R6
B3
A4
G3
A10
B10

Oscillator, Board2

TSG-1
Chassis Layout
(top view)


R2
R14
R1
R13
R9
R8
L1
T1
Board 2
Board 1
S1
S2
A
G
P

TSG-1 PARTS LIST

B_1	9 volt battery
$C_{1, 9, 10}$	.05
C_2	5
$C_{3, 6}$	.005
C_4	.0005
C_5	160
C_7	.001
$C_{8, 11}$	220 pt
D_1	1N442B
$D_{2, 3}$	1N91
L_1	344 (T-1 3/4 Midget flanged 10v. .015 amps)
Q_1	2N270
$Q_{2, 3}$	2N1098
R_1	1K
R_2	100K POT IRC Type RQ
$R_{3, 5, 11, 15}$	10K
R_4	1 MEG
R_6	470 K
R_7	560 K
R_8	50 K POT IRC Type RQ

R9	500 POT IRC Type RQ
R10	75
R12, 16	100K
R13	6.2K
R14	7.5K POT IRC Type RQ
R17	670 ohms
S_1	DpDt, center off
S_2	3 Pole 10 pos wafer switch, Centralab 1009
T_1*	Stancor P-6134 or equiv.

Miscellaneous

1. Light socket
   DIALCO #162-8430-937
2. Construction boards
   USECO terminal boards

   Litton Industries
3. Case
   H. H. Smith Meter case

   2257 medium size
   6-13/16 x 5-9/32 x 2-5/16

   2260 cover
4. 3 banana jacks-2 red, 1 black
5. Battery clip
   Battery snap contacts

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*Resistors are in ohms and capacitors are in mfd unless otherwise stated. Changing T_1 may change the frequency of the oscillator slightly.

TSG-1 CONSTRUCTION NOTES

The TSG-1 is assembled in the case using the removable cover as the bottom plate. The terminal boards are attached to the sides of the case. R2 and R14 are mounted on the rear of the case and R9, R8, L1 socket, T1, S1, and S2 are attached to the top of the case. The black banana jack, G, is mounted in the center of the front of the case and the two red jacks, A and B, are mounted one to the left, and one to the right of center. The chassis layout diagram is drawn actual size and can be used to help determine parts placement.

Construction of the TSG-1 should follow as closely as possible these steps:

1. Lay out parts placement on case.
2. Drill all necessary holes.
3. Mount all parts on terminal boards using only lower half of each terminal where possible.
4. Mount all components and terminal boards in case except S2.
5. Prewire S2 connecting jumpers and components as follows:

Connection	S2 Position
Jumper	A5 to A9
Jumper between	G1, 3, 4, 5, 8, and 9 (do not solder)
Jumper	G7 to G10
Jumper	B3 to A4
Jumper	B5 to B8
+ of D1	to G5
C7 between	B8 G8

6. Make connections between terminal boards and all components except S2 (see connection table).
7. Mount S2 in case.
8. Make connections between terminal boards and components, and S2 (see connection table).
9. Solder all connections not previously soldered.
10. Mount battery clip on bottom plate so that it is positioned below R8 and R9 when bottom plate is attached.
11. Attach battery snap contact to battery terminals and fasten bottom plate.

Connection Tables

In the tables below the terminal board containing the components for the flip-flop circuitry is called "Board 1", and the terminal board containing the components for the oscillator circuitry is called "Board 2".

R2 connections

Wiper	to	common at SIB
Terminal 1	to	R1 (Board 2)
Terminal 2	to	no connection

R8 connections

Wiper	to	C9, C10, B4 of S2
Terminal 1	to	B8 of S2
Terminal 2	to	G9 of S2

R9 connections

Wiper	to	Terminal 1 of R9
Terminal 1	to	R12 (Board 1)
Terminal 2	to	Terminal 2 of L1

R14 connections

Wiper	to	Terminal 1 of R14
Terminal 1	to	R13 (Board 1)
Terminal 2	to	R15 (Board 1)

L1 connections

Terminal 1	to	R17 from Board 1, Terminal 1 S1A
Terminal 2	to	Terminal 2 R9 (see above)

T1 connections

Primary

1 yellow wire	to	R5 (Board 2)
1 yellow wire	to	Q1 collector (Board 2)
1 red wire	to	C4 (Board 2)

Secondary

1 black wire	to	Terminal 1 R8
1 black wire	to	D1 -

D1 connections

D1 -	to	T1 black wire
D1 +	to	G5 of S2

S1 connections

A. (closest to Board 1)

Common	to	Battery -
Terminal 1	to	Terminal 1 L1, Terminal 2 S1A
Terminal 2	to	Terminal 1 S1A

B. (closest to T1)

Common	to	Q1 Base Board 2, Wiper R2 (see R2 above), A3 of S2
Terminal 1*	to	C1 (Board 2)
Terminal 2	to	C2 (Board 2)

S2 connections

Wafer A

Position			
Common		to	Jack A (Left most when viewed from top)
1		to	R13 (Board 1)
2	not used		
3		to	Common of S1B
4		to	C4 (Board 2)
5		to	A9 of S2
6	not used		
7	not used		
8		to	D3 (Board 1)
9		to	C11 (Board 1)
10		to	R4 (Board 2)

Wafer G

Position			
Common		to	Jack G (center jack, black)
1		to	R13 (Board 1)
2	not used		
3		to	Q1 emitter (Board 2)
4		to	Battery +
5		to	D 1+
6	not used		
7		to	C5 (Board 2)
8		to	C7
9		to	R8 Terminal 2 (See R8 above)
10		to	G7 of S2 (jumper)

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*This is the terminal which is in the circuit when the switch lever is in the position away from the front of the case or away from jacks A, G, and B.

Wafer B

Position		
Common		to Jack B (right red jack when viewed from top)
1	not used	
2	not used	
3		to A4 of S2 (jumper)
4		to Wiper R8 (see R8 above)
5		to B8 of S2 (jumper), Terminal 1 R8 (see R8 above)
6	not used	
7	not used	
8		to C7 (Switch S2)
9		to C8 Board 1
10		to R7 Board 2

Labeling the Controls and Jacks

Components	Label
R2	Frequency Vernier
R8	Trigger Level
R9	Trimmer
R14	Balance
S1*	HI OFF LOW
S2	FS1
Jacks	
A	A
G	G
B	B

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*The HI position is furthest from the front of the case.

TSG-1 ALIGNMENT

Transistors Q-2 and Q-3 are the active elements of the flip-flop circuitry. To assure correct operation of the circuit, the voltage drop across R17 when Q3 is on should be equal to the voltage drop across L1 and R9 when Q2 is on. To begin with, set R14 so that its resistance is equal to R13. Next set FS1 (S2) to position 9. A VOM (20,000 ohms/volt) may be used to measure the collector voltage of Q3 (jack A and G) and the collector voltage of Q2 (jack B and G) with the switch in position 9. By turning R8, the trigger can be reduced to a level which will not operate the flip-flop but permit leaving either Q2 or Q3 in the ON state. Now put S1 in the "low" position and set R8 to a position at which L1 flashes on and off. Next turn R8 until L1 stops flashing and remains off. Transistor Q3 is now in the ON state, so measure the negative DC voltage between jack A and G. Turn R8 until L1 begins flashing again, and then turn it back until L1 stops flashing and remains ON: Q2 is now in the ON state. Measure the negative DC voltage between B and G, and adjust R9 until this voltage is the same as the voltage between A and G when Q3 was in the ON state. This completes the preliminary alignment procedure, so set R8 to a position at which L1 begins flashing again. Other adjustments are to be made following the instructions accompanying the oscilloscope program.

APPENDIX II

ADMINISTRATOR'S MANUAL
FOR
TEKTRONIX 545A
INSTRUCTIONAL PROGRAM

ADMINISTRATION OF THE TEKTRONIX PROGRAMMED BOOK

1. General. It is necessary that the strictest of policies be observed in the administration of the A.S.A., Inc., Tektronix Programmed Book to the Goodfellow test population. These notes outline these policies. Both the program and the method of instruction are being evaluated. In order that this section of Study 1414 II may be effective, administrator influence must be minimized...especially where this influence may be inconsistent from one individual subject or group of subjects to another.

2. Help to Subjects. The only type of help which an administrator may give a trainee, if that trainee is to be kept as a subject, is to read properly a misspelled or unclearly printed word to him. If the subject does not understand any portion of the program the administrator should take note of this, and at all times maintain a cumulative file of these notes for all training sessions for which he is responsible. When a trainee indicates such a lack of understanding, he should be advised exactly as follows:

"If the book does not make sense to you, go ahead to another problem and try it. I have been instructed to give you no help at all with the program. It should explain itself, but where it doesn't do this we keep track of this and later we will change it so that no one has trouble at that spot."

The administrator should be familiar enough with the program to know what questions are answered by the program text. Often a subject will ask a question which will be answered at a later point in the program. When this happens the administrator should say:

"Please go ahead with the program...I think you will find the answer later on. If you do not and this causes trouble, call me again and we will list this as a program discrepancy."

If such a discrepancy occurs the administrator should record it and advise the subject to continue as best he can. If the subject cannot continue, the administrator should render whatever help is necessary, record in complete detail what help is given, and note on records that the records of this and previous S's have been contaminated. The program will then be amended or corrected on the basis of the discrepancy noticed. The administrator should be cautioned to carefully discriminate generator variability from program discrepancy. If the question asked is due to some malfunction of variability of the signal generator, the generator should be adjusted (See generator settings below.)

3. Instructions to the Subject. When a trainee has been greeted and shown to a training/testing booth, the administrator will read the following instructions:

"I know it sounds funny to read these directions to you, but it is very important that the same thing is said to everyone. This is a scientific evaluation of a self-instructional program. Actually the program you are about to learn from has been tried out on other Air Force persons and has been corrected. Now it must be given to many persons in the same way to find out if it works to teach as well as we think it will. There may be some little errors, but you should be able to get along all right if you read very carefully. If you do not agree with an answer in the program, note this fact in red pencil on your Response Sheet and then continue with the program. Feel free to ask questions, but be prepared if I have to read the answer to you. This is all part of being careful that no one gets help that everyone doesn't get. (Pause) Please write your name on the top of the Response Sheet. (Point out to S.) Do not go beyond Section III in the program today. Now go ahead and read the introduction to the book. Call me if you are missing any equipment by flipping the toggle switch at the back of the Signal Generator." (The administrator should point out the switch at this time.)

This should be sufficient, if the booth has been set up properly, to get the subject underway. The instructions above should be rehearsed by the administrator prior to program administration.

4. Booth Equipment
   A. 2 probes (P-6006)
   B. 1 ground cord
   C. 1 response sheet
   D. 1 program
   E. 2 pencils--one with regular lead, the other with red.
   F. 1 oscilloscope
   G. 1 signal generator

5. Instructions to Administrator
   A. After setting up the oscilloscope and generator (see settings below), the probes should be disconnected from the oscilloscope, the power switch should be turned off, and the power line should be unplugged from the wall socket. The grounding wire (red) and probes should be coiled within easy reach of the S.

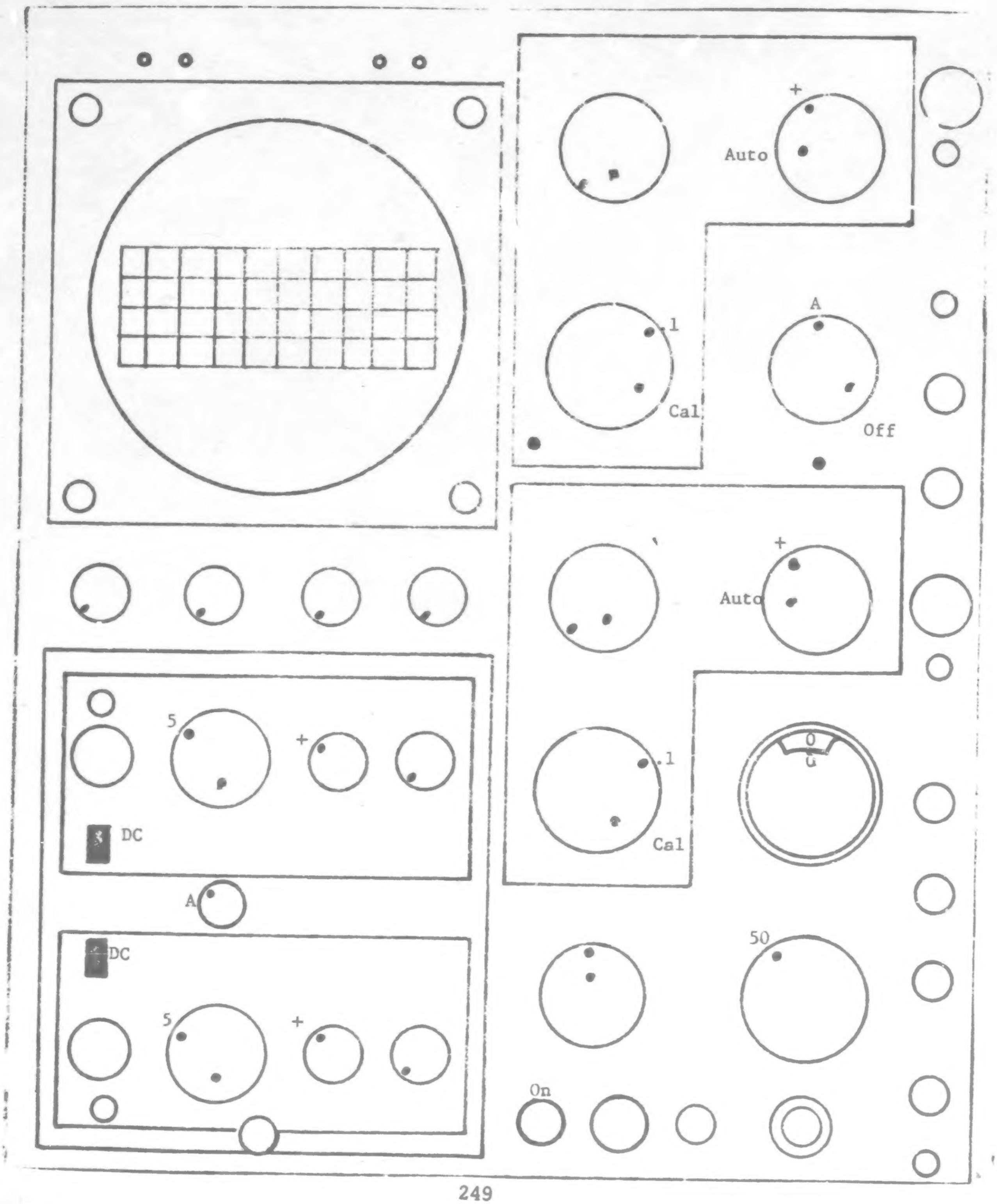
5. Continued

B. Be sure to put down start and finish times for program on both first and second days.

6. Generator and Oscilloscope Settings

A. FS on generator to Pos. 5.
B. Range switch to High.
C. Test Jack A
   1. Square wave--4 CM per cycle on oscilloscope. Time/CM at 1 Millisecond. 250 CPS.
D. Test Jack B
   1. 2 CM per cycle on oscilloscope. TIME/CM at 1 Millisecond. 500 CPS.
   2. Voltage level at 240 Volts. NOTE: If voltage is not 240, adjust level then refine frequency adjustment.
E. FS to Pos. 1, Test Jack A--Measure P-T-P of Square wave to 2 Volts. Adjust level to obtain 2 Volts.
F. Recheck D 2 above. If more than 3% out of requirement call maintenance.
G. See Figure 5 for Oscilloscope settings after the generator has been set.

Figure 5. Oscilloscope Settings At Beginning of Program


+
Auto
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Cal
A
Off
+
Auto
.1
Cal
O
G
5
+
DC
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DC
5
+
50
On